AQUATIC AND FISHERIES SURVEY OF THE UPPER VICTORIA NILE

A REPORT PREPARED FOR AES NILE POWER BUJAGALI HYDROPOWER PROJECT

FINAL REPORT

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Prepared by:
National Agricultural Research Organization
Fisheries Resources Research Institute
P.O. Box 343, Jinja, Uganda
Fax: 256-43-120192
Tel: 256-43-120384

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Acronyms

μg	micrograms
μS	Micro Semen
<	Less than
CITES	Convention on International Trade in Endangered Species
Cm	Centimetre
CPUE	Catch per unit of effort
DAFOR	Dominant, abundant, frequent, occasional, & rare.
DO	Dissolved Oxygen
DWD	Directorate of Water Development
EAFRO	East African Fisheries Research Organisation
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
FIRRI	Fisheries Resources Research Institute
Ind.	Individuals
Kg	Kilogram
Km	Kilometre
L	Litre
M	Metre
Mg	Milligrams
MW	Mega Watts
NEMA	National Environmental Management Authority
P	Probability
Q	Quarter
Sp	Species
SRP	Soluble Reactive Phosphorus
TN	Total nitrogen
TP	Total phosphorus
UEB	Uganda Electricity Board

1. Introduction

The aquatic ecosystem of the Upper Victoria Nile is part of a wider complex of water bodies (lakes and rivers) in Uganda (Fig. 1) that is of immense socio-economic importance, especially the fisheries. A source of food, income, energy, irrigation and drinking water, the protection, sustainable use and management of the Upper Victoria Nile water resources are vital to Uganda's economy. The Upper Victoria Nile, due to its abundance of socio-economic benefits, provides a significant contribution to Uganda's economy. The fisheries contribute to the sector as a major source of the export earnings, second to coffee (NEMA, 1996), sustain small fishing villages, provide income and generally improve nutrition. Apart from the socio-economic significance of the fisheries, the riverine features of the Upper Victoria Nile, especially its hydropower potential, distinguish this river from the rest of the aquatic ecosystems in the country.

Hydropower, a valuable component of Uganda's economy, is another aquatic resource related to the Upper Victoria Nile. The dual exploitation of hydropower and the fisheries can fuel the country's economy, however, their mutual compatibility and sustainability remain a management challenge. With a growing population and energy demand, the Nile hydro-power potential may be considered the major alternative to wood fuel which presently accounts for 94% of the total energy consumed in the country (NEMA, 1996). Soil erosion and water quality changes resulting from deforestation, adversely affect the Upper Victoria Nile and consequently, the fisheries. To conserve the ecological dynamics of the riverine system, alternative energy sources to wood-fuel have been identified, specifically hydropower, which would alleviate some of the energy burden. Harvesting this new energy source would benefit Uganda's economy and environment, provided the fisheries were maintained.

With growing interest in developing alternative power sources, such as hydropower, many organizations and committees have been formed to necessitate sustainable management of natural resources. Since the early 1970's, the World Bank has taken particular care to ensure that the hydropower and irrigation projects it has financed have heeded the environment. 'Dams and the Environment, Considerations in World Bank Projects' (1989), a World Bank technical paper, discusses the cost-benefits of proposed dam projects by weighing the potential environmental impacts against the economic benefits. It also addresses environmental concerns and proposes mitigation measures. Similar global policies include the Convention on Wetlands of International Importance, and the Convention on International Trade in Endangered Species (CITES). The National Environmental Statute of 1995 outlines policies and regulations in Uganda for prevention of environmental degradation and is enforced by the National Environment Management Authority (NEMA). Environmental impact assessments (EIA), monitoring plans, environmental action plans and audits are NEMA-legislated requirements in Uganda for all development projects to preserve the environment.

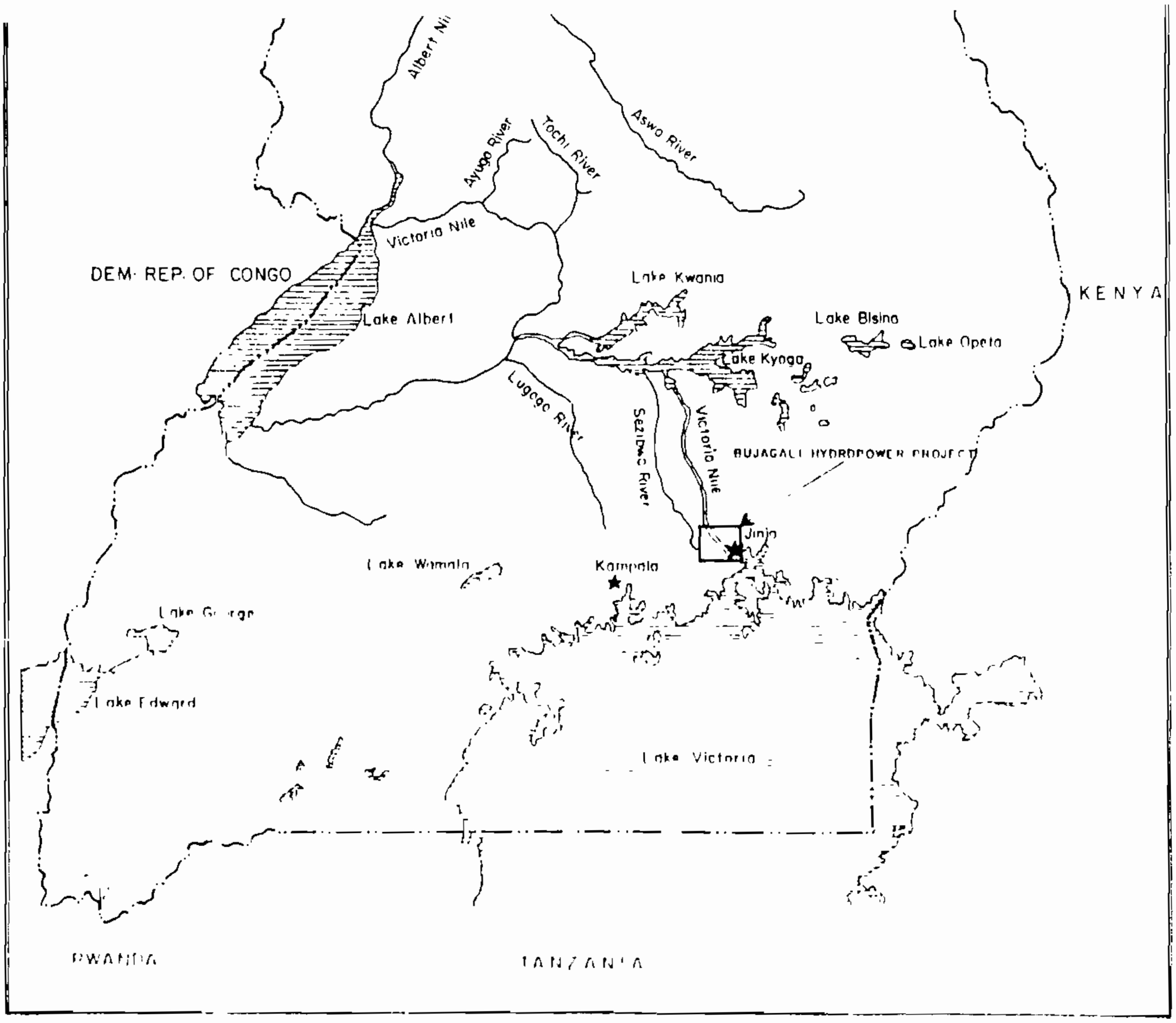


Fig.1 Map of Uganda showing the Aquatic systems and location of Project site at Dumbell Island on upper Victoria Nile.

AES Nile Power (AESNP) has proposed that a 250 MW hydropower plant be constructed on the Upper Victoria Nile (Fig. 2) at Dumbbell Island, 2.5 km downstream from Bujagali Falls. To comply with NEMA's mandate, an Environmental Impact Statement (EIS) dated March 1999, among other documents, was submitted to the Government of Uganda. Subsequently, a baseline aquatic monitoring and fisheries survey of the Upper Victoria Nile, a recommendation of the EIS, was commissioned to the Fisheries Resources Research Institute (FIRRI). The survey would be used to assess and mitigate potential environmental impacts of the hydropower plant pre, post, and during construction with special reference to the fisheries.

Scope of the Aquatic Monitoring and fisheries Survey

The proposed Bujagali Hydropower Plant is located at Dumbbell Island along the Upper Victoria Nile, a 100 km corridor connecting Lakes Kyoga and Victoria (Fig. 2 & 3). According to literature, these two lakes and this section of the River Nile share many fish species. Hence, the overall objective of the survey was to determine potential pre, during and post construction environmental impacts of an artificial barrier on the fish and aquatic ecology of the Upper Victoria Nile.

The scope of work consisted of compiling baseline data of the hydrology, water quality, and ecology (invertebrate, fish, and macrophyte surveys) of the Upper Victoria Nile in the region surrounding the proposed hydropower plant. Four quarterly surveys were completed that gathered seasonal data over the year 2000, incorporating the short and long rainy seasons and the short and long dry seasons. The sampling area consisted of four sites, one upstream and three downstream of the proposed project (Fig. 3) each with transects across the width and along the banks of the river. Standard sampling methodologies for the assessment of aquatic ecosystems were adhered to in the field and laboratory. The results of these surveys are detailed in four reports conducted from the 16th to 28th of February, 5th to 14th of April, 1st to 8th of August, and 20th to 27th of October 2000. The data assembled over the four surveys were reviewed to establish overall pre-construction environmental conditions.

The following specific objectives were set for the baseline study and were addressed in each of the surveys:

- To study an area large enough as to encompass significant impacts anticipated both upstream and downstream of the site at Dumbbell Island,
- To monitor hydrological and water quality determinants,
- To study algal species composition
- Determine macrophyte composition and distribution,
- To carry out invertebrate surveys,
- To carry out fish stock (relative abundance) and fish catch surveys,
- To study the biology of fishes and food webs.

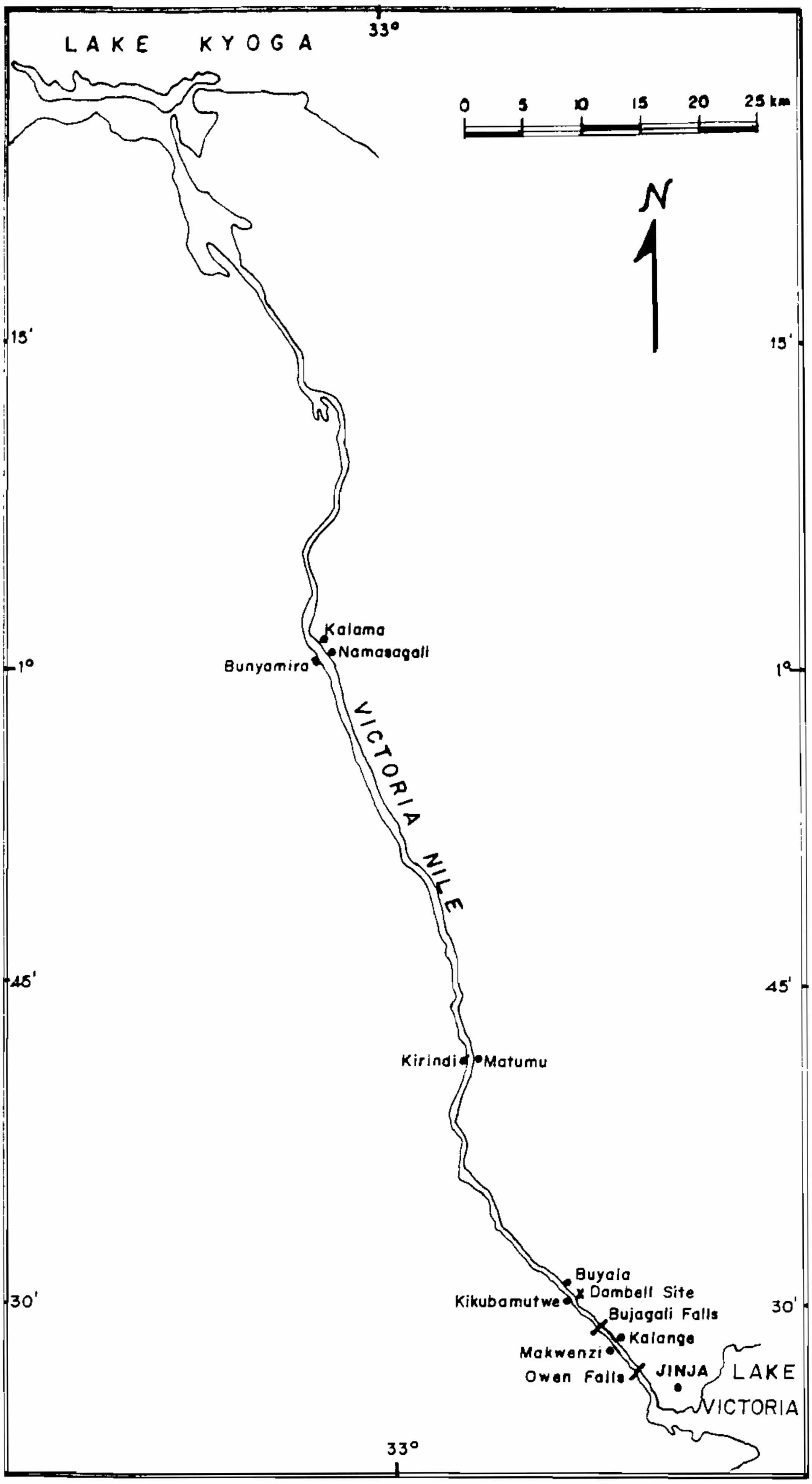


Fig. 2 A map of upper Victoria Nile indicating position of Project site at Dumbbell Island and location of the sampled transects.

Ecological investigations carried out on the two lakes (Victoria and Kyoga) in the last two decades show a steep decline in fish species diversity due to overfishing, predation pressure by the Nile perch and environmental degradation including eutrophication and water hyacinth infestations. In contrast with these investigations, much less has been reported or studied on the Upper Victoria Nile.

Little research and few studies have been completed with respect to fish migration within the Upper Victoria Nile. No similar study was conducted at the time the Owen Falls Dam was constructed. It is also not known whether or not fish could ascend the now semi-submerged Ripon Falls. Furthermore, there are other potential barriers (e.g. Kalagala and Bujagali Falls) whose effects on fish distribution patterns and behavior are not known. However, it can be determined from taxonomic studies (e.g. Greenwood, 1966; Beadle, 1974) that a 'nilotic fauna' is separated from the Victorian fauna by Murchison Falls even though the River Nile flows from Lake Victoria through Lake Kyoga and downstream through Lake Albert towards Sudan. Major factors that may provide insight into environmental impacts of the proposed project on fishes and fish populations are the number and density of fish species in the different sections of the river, habitat characteristics, keystone species, trophic interactions, breeding and migratory species.

This report is structured according to the guidelines provided by AESNP. After the introduction, sampling methodologies for all the physical and biological parameters and surveys are outlined in **Section 2** followed by the background results in **Section 3**. This section outlines pertinent water quality (e.g. dissolved oxygen, temperature, pH, suspended solids, oils and grease, nutrients), phytoplankton (algae), aquatic macrophytes (mostly submerged and floating plants), micro-invertebrates (zooplankton), and macro-invertebrates (e.g. insects, insect larvae, snails) results. It also considers spatial and seasonal trends and identifies keystone species. Fish species composition and ecology, important commercial and non-commercial fish species, and potential post-construction changes in the ecology are elaborated in **Section 4**. An overall discussion of the results, along with conclusions and recommendations, are presented in **Section 5**. As the report is based on the four detailed surveys, the four reports should be used as reference during the review of this document.

2. General methodology and data collection

Four study transects (Fig. 2 & 3) were identified by a team of FIRRI scientists (Annex C) together with AESNP representatives. These were: *Kalange-Makwanzi* (transect 1), upstream of proposed dam construction site at Dumbbell Island, *Buyala-Kikuba Mutwe* (transect 2), *Matumu-Kirindi* (transect 3) and *Namasagali-Bunyamira* (transect 4) at increasing distances downstream of Dumbbell Island.

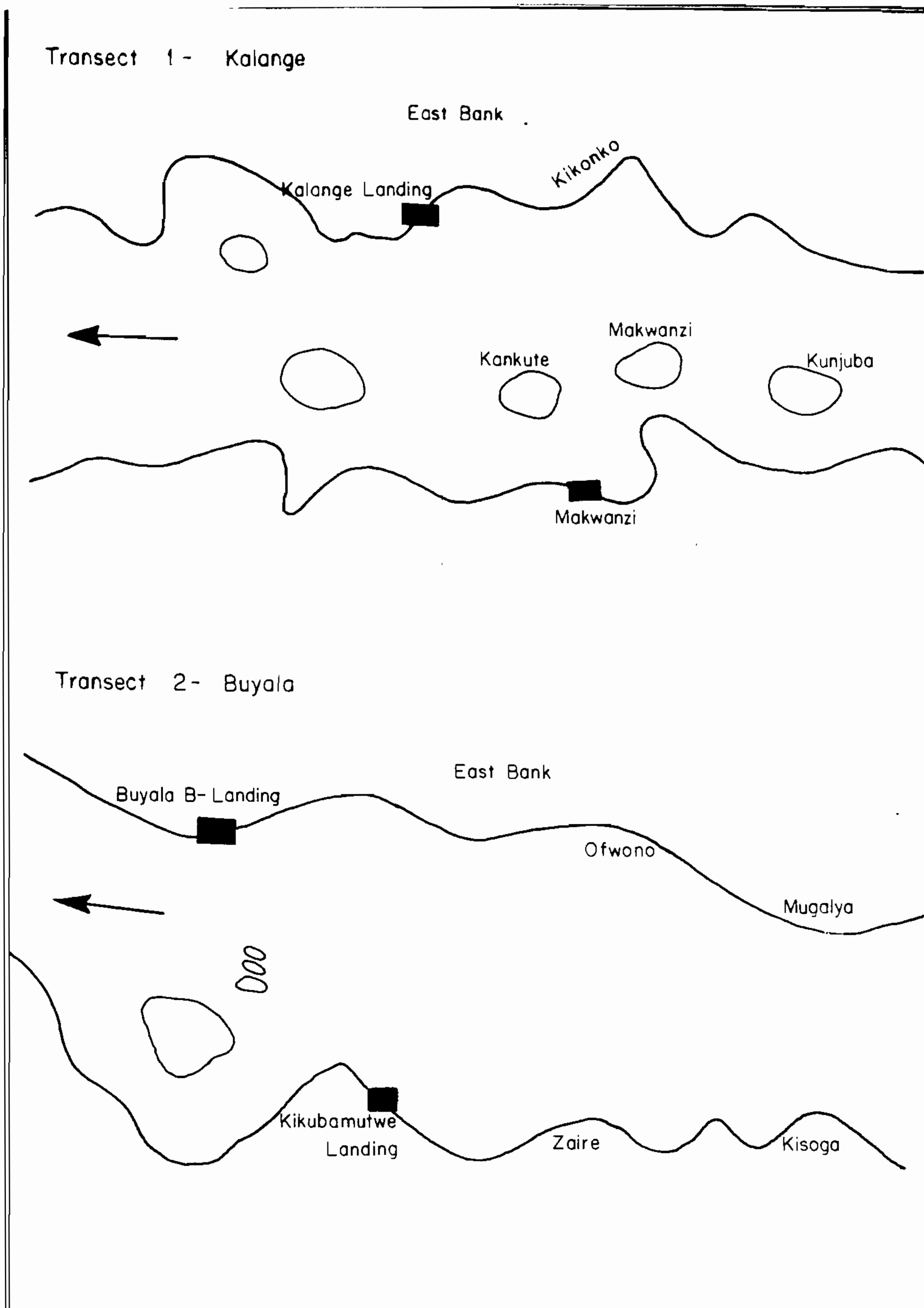
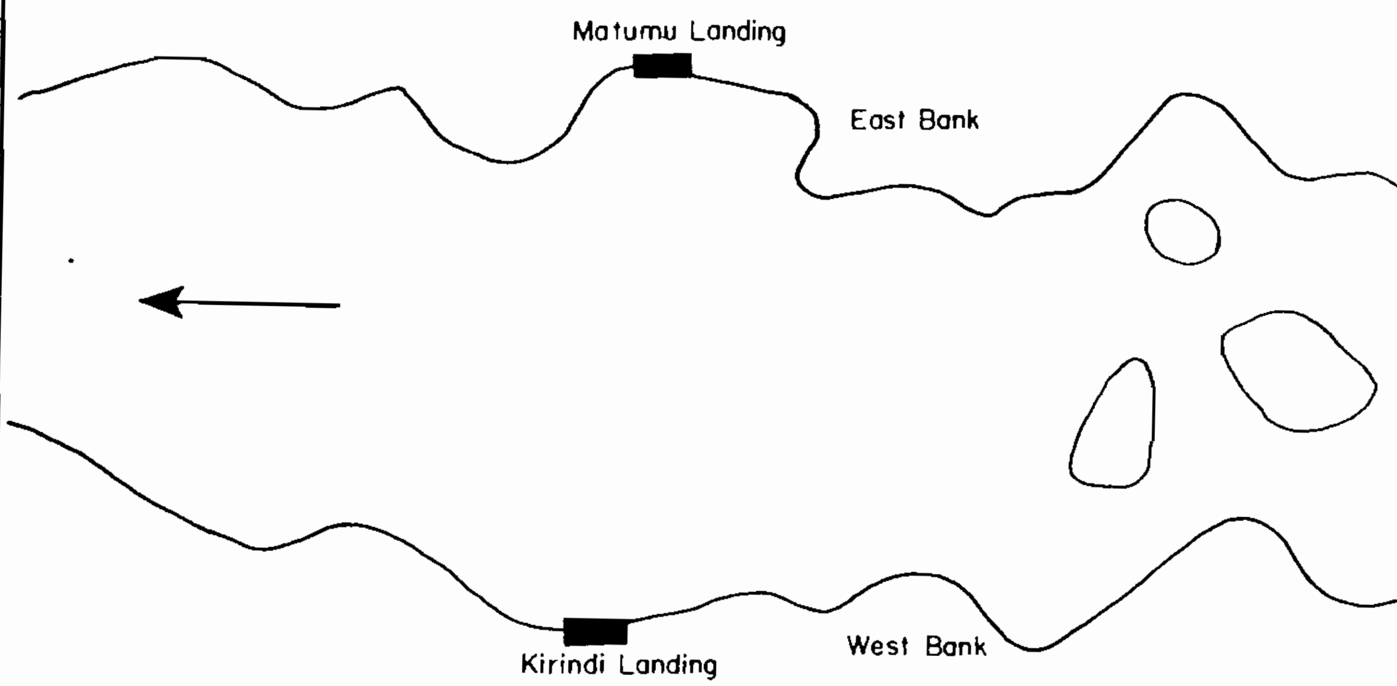
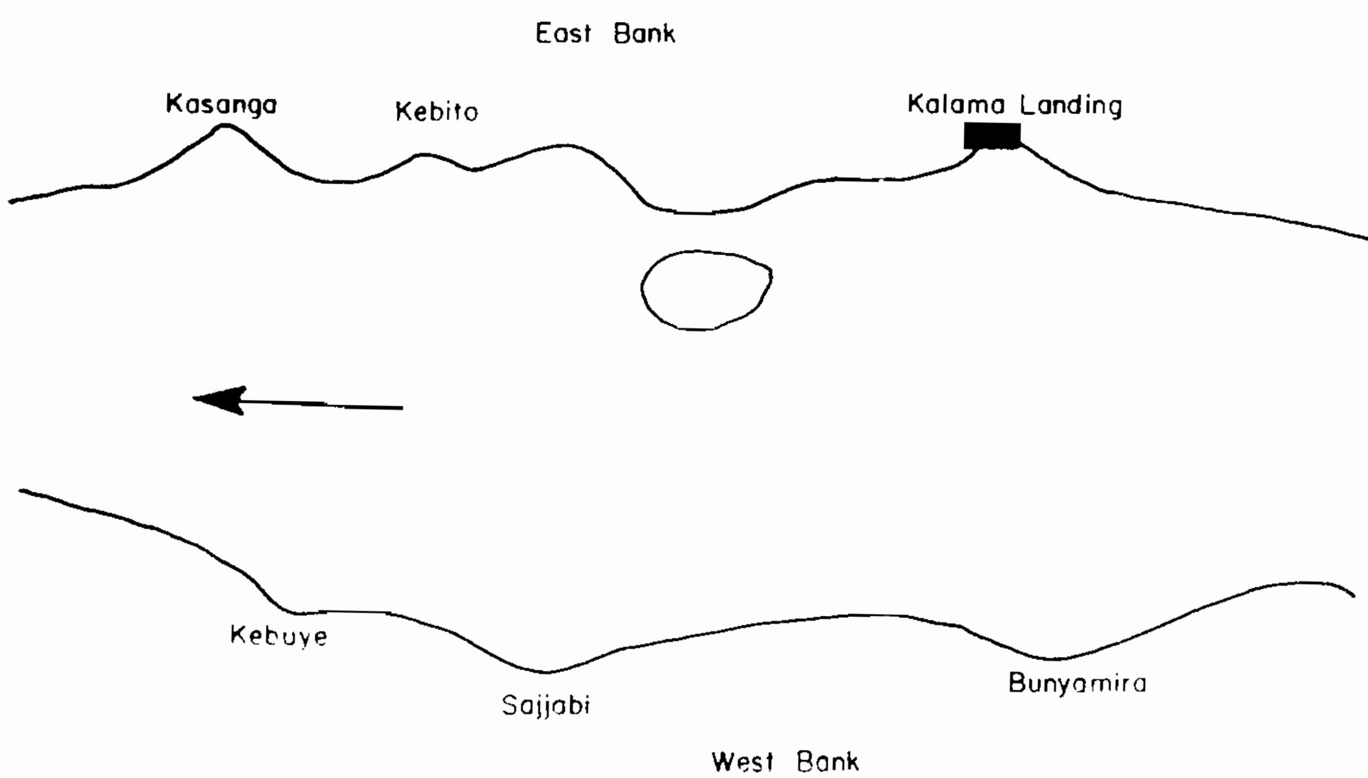


Fig.3 Sketch map showing the four sampled transects on the other Upper Victoria Nile.

Transect 3- Kirindi



Transect 4- Namasagali



Quarterly sampling surveys for water quality, algae, aquatic macrophytes, invertebrates (micro and macro) and a fishery survey (biology, ecology, species composition, abundance, importance and volume of fish catch) were carried out during February, April, August and October 2000 respectively.

Water quality:
In situ measurements (dissolved oxygen, temperature, conductivity, and pH) were carried out using Orion portable meters and a secchi disc was used to measure water transparency. A van Dorn water sampler was used to draw water samples, which were analysed for nutrients following standard methods (Greenberg, 1992, Stainton *et al* 1977). Suspended solids were determined by weight difference, oil/grease concentrations were measured using the partition-gravimetric method (Greenberg, 1992) and chlorophyll-a concentrations were obtained using the standard spectrophotometric method (Greenberg, 1992). Algal biomass and composition were determined using the standard spectrophotometric method and the methanol method and appropriate keys (Stainton *et al*, 1977).

Aquatic macrophytes:
Plant identification along the riverbanks was carried out from a canoe. Other specimens were collected from one metre square quadrants and pressed. Further identification using appropriate keys and quantification based on the DAFOR system were carried out in the laboratory and at the Makerere University herbarium.

Invertebrates:
Micro-invertebrates were sampled using Conical Nansen nets, identified and counted under inverted microscopes using suitable identification keys. A ponar grab was used to sample macro invertebrates in sediments and macro-invertebrate nets were used for those in macrophyte roots. The collected specimens were identified using appropriate keys and enumerated.

Fish biology, ecology, distribution and abundance:
Graded gillnet mesh size nets and beach seines were used to sample various habitats for fish. The fish were preserved in an ethanol and formalin mixture and were identified and sorted. Biometric measurements were taken and other biological parameters, including food items of fish and egg counts were recorded.

Fish catch survey:
Commercial fish species were identified from known number of canoes, gear sizes and fishing methods. Fish samples were taken for biometric measurements. The number of active canoes and full time jobs supported by the fishery were recorded. The estimated total yield and value were computed.

3. Background Results

3.1. Water Quality Characteristics

Spatial Differences and Seasonality of Key Physical Parameters

No systematic spatial (i.e. longitudinal) trends were revealed in physio-chemical parameters from transect 1 (Kalange-Makwanzi, upstream of Dumbbell Island) to transect 4 (Namasagali-Bunyamila, downstream of Dumbbell Island). The mean conductivity, suspended solids, pH, dissolved oxygen (DO) and temperature values varied widely between transects. This could be attributed to the incongruity of site locations resulting from varying river and shoreline conditions with differing water regimes. For example, the upstream study area was characterized by fast flow regimes accentuated by rapids/falls (e.g. Bujagali and Kalagala among the most prominent) and the bends in such sections contained quieter embayments which were also sampled. In contrast, the downstream sites were characterized by a more regular and gentle flow across the width of the channel.

Secchi depth, a measure of water transparency, generally increased downstream with transect 4, showing the clearest water during all four seasons. This pattern was closely correlated with a comparatively low suspended load. The slower flow across the wide wetland-buffered channel was probably responsible for the low level of suspended solids. The high suspended solids load upstream could have been attributed to soil erosion from the devegetated banks in the Jinja area, and agricultural plots between transect 1 and transect 2 (1^{st} & 2^{nd} Quarter AESNP Reports, 2000).

In contrast to longitudinal patterns, the seasonal changes had a clearer influence on many of the physical parameters. For example, regarding dissolved oxygen, the wet seasons were associated with a lower mean DO (5.8 – 7.2 $mg.l^{-1}$ during the second quarter, and 5.5 – 9.0 $mg.l^{-1}$ during the fourth quarter). In contrast, dry seasons experienced higher DO values (7.4 – 8.2 $mg.l^{-1}$ during the first quarter and 7.1 – 9.0 $mg.l^{-1}$ during the third quarter) across all transects. However, transect 3 had the highest DO (7.2 – 9.0 $mg.l^{-1}$) in all seasons when it may have been expected that a systematic longitudinal trend (from upstream to downstream transects) in physio-chemical conditions of the river would also be imposed on the seasonal trends. Conductivity behaved similarly with respect to season with wet seasons registering higher values (99 – 108 $\mu S.cm^{-1}$ during the second quarter and 121 – 134 $\mu S.cm^{-1}$ in the fourth quarter) but without systematic longitudinal patterns. This was also a trend in the pH values and the sechhi depths. Suspended solids were highest during the second quarter as compared with the first and third quarters.

ANOVA ($p<0.05$) on mean nutrient concentrations revealed the following patterns: Transect 4 contained the highest TN (478 – 5120 $\mu g.l^{-1}$) in all seasons;

TP concentrations were highest during the rainy seasons (varying between 72 – 133 µg l^{-1}in the second quarter and 70 – 88 µg.l^{-1} in the fourth quarter) without any noticeable longitudinal pattern; and SRP values were also generally higher (26 – 52ug.l^{-1}) during the wet seasons. There was an inverse relationship between SRP and chlorophyll-a values, most prominent in the first quarter. The elevated chlorophyll levels may have been due to the dominant blue-green algae (Cynophycea).

Oil and grease levels did not appear to be influenced by seasonal or spatial differences. The concentration of these substances was localized and seemed to be associated with direct use of localities or adjacent activities related to human activities (e.g. fishing, local household washing, motorized boat transport, car washing and trucks).

Most physical parameters were influenced by the increase in precipitation. Soil erosion at the first three transects due to extensive cultivation, in combination with rainfall resulted in more agricultural runoff into the river. The additional inputs from the agricultural fertilizers, chemicals, and the atmosphere, due to increased attenuation from the precipitation, resulted in an increment in the numbers of ions in solution in the river and elevated nutrient levels.

3.2. Algae and Aquatic Macrophytes

3.2.1. Algae (phytoplankton)

Phytoplankton density and diversity appeared to be related to water quality. The *Cyanophycea* (blue-green algae/cyanobacteria) were the dominant and most diverse class in all quarters at all transects. The key species were *Microcystis Anabaena, Cylindrospermopsis* and *Planktolyngbya.* The degree of *Cyanophycea* dominance in the investigated area ranged from 49 to 78% of counts with the highest counts being registered during the wet seasons (second and fourth quarters). Chlorophyta (green-algae) were the next most dominant class accounting for 12 to 27% of counts in the four quarters, represented mainly by *Ankistrodesmus* and *Scenedesmus*. The *Bacilliriophycae* (diatoms) were less common with *Nitzichia* as the most abundant genus in the class. Other, less abundant groups occurring in the transects were the Cryptophyta, Peridineae, Protozoa and Euglenophyta.

The phytoplankton are of great importance to the fisheries as they are a source of food for zooplankton and juvenile fishes. Most juvenile tilapia stomachs contained the more common phytoplankton (*Cyanophyceae, Chlorophyceae, Bacillariophceae*) as did the young stages (<20 TL) of *O. niloticus*. The stomach contents of the *Synodontis afrofischeri* at the fourth transect included epiphytic algae (*Gonatozygon*), detrital and higher plant material, and food items of terrestrial origin. These patterns illustrate the significance of phytoplankton in the food webs of the shallower habitats along the banks where nutrient levels influenced the abundance of the algae.

In Lake Victoria, the dominance of blue-green algae (*Cyanophyta*) is indicative of eutrophic conditions due to both nutrients and light (Hecky, 1993, Mugidde, 1993). However, the algal biomass in the Upper Victoria Nile is more dependent on nutrients as the algae flourished despite low secchi transparency.

3.2.2. Aquatic Macrophytes

Apart from diversifying habitat structure and providing refuge from predation, aquatic macrophytes (higher plants growing in water-dominated environments) provide fish feeding, breeding and nursery areas. By virtue of their terrestrial anchorage along the riverbanks, some of the plants are also allochthonous (external) sources of materials (from leaves, terrestrial insects, bird droppings, etc) which feed into the food chains of fish.

The quarterly surveys (see 1st – 4th Quarter AESNP Reports) reveal that at least 82 aquatic macrophyte species (70% of them obligate aquatic macrophytes, i.e. euhydrophytes) were encountered in the study area. The macrophytes could be separated out into four major categories based on cover importance. The first category are the emergent species (e.g. papyrus, reeds); followed by floating-leaved and related forms (water hyacinth, hippo grass, Nile cabbage); then the semi-terrestrial species (the tree, *Brousenetaria papyrifera*, shrubs – *Alcornia* and herbaceopus species – *Melanthera*, *Ipomoea*, *Commellina*) and finally the submerged species (*Ceratophyllum*, *Vallisenaria*, *Potamogeton* and *Najas).*

Species diversity tended to increase with distance downstream. Human activities such as cultivation along river banks and on islands, and cattle grazing, appeared to have a negative effect on some macrophyte development. However, the initial low macrophyte diversity in the first quarter sampling, especially at transect 4, was more of reflection of poor sampling of differing habitats (e.g. the canals, other water inlets and the water column) as opposed to low species diversity. As a result, transect 4 appeared to be mono-specific having only extensive papyrus fringes.

In general, seasonal effects over the four quarters were reflected in the changing cover type ratings. However, in all the quarters, transects 1 and 2 were dominated by hippo grass and water hyacinth both accounting for about 60% of the vegetation along the riverbanks. Some other plant species (e.g. the trees, shrubs, crops, climbers, such as the various species of *Ipomoea* and *Lepistemon oweliensis,* were also present throughout the study due to their perennial nature. It would be expected that macrophyte abundance would be greatest during the dry seasons as compared to the wet seasons and this was evident in contrasting the cover type ratings of the third and fourth quarters. Changes in cover type, species diversity, and abundance of existing macrophytes reflected the seasonal trends.

The water hyacinth, regardless of its apparent reduction and control by the introduced weevil, remains a significant concern in the Upper Victoria Nile. Extensive cultivation at the first three transects resulting in higher concentrations of SRP, TP, and TN, increased the abundance of water hyacinth. The *Vossia cuspidata* and *E. crassipes* are closely associated genera and, as a result, co-occurred along the river shoreline. The *Vossia cuspidata* was dominant at the first three transects and consequently, *E. crassipes* was also abundant. The degradation of wetland buffers have also fuelled proliferation of the water hyacinth resulting in an average cover rating of "Abundant". There is the possibility of *E. crassipes* resurgence, particularly in the impoundment. This would have a major impact on the fisheries and hydroelectric plants along the Upper Victoria Nile. The introduced weevil could restrict the height and vigor of the weed, however, the weevil had done little damage to the hyacinth at the Namasagali/Bunyamira transect. Identifying the optimal growing environment and water conditions in order to prevent a resurgence of this weed is imperative for the prosperity of any industry dependent on the water resources of the Upper Victoria Nile.

3.3. Micro-invertebrates (Zooplankton Composition, Diversity and Abundance)

Several studies undertaken by FIRRI have demonstrated that fish larvae irrespective of species, ingest almost entirely zooplankton as their first external food. In addition, juvenile fishes, adult *Rastrineobola argentea* (mukene) and several haplochromine fishes depend on an invertebrate diet dominated by zooplankton. Such fishes belong to the crustacea-zooplankton trophic category. Therefore, the abundance and distribution of such fishes is linked with the zooplankton populations and may be used as an indicator of the quality of the fish habitats.

The four quarterly surveys of the Upper Victoria Nile (see 1st – 4th Quarter AESNP Reports) revealed three broad taxonomic groups (Copepoda, Cladocera, Rotifera) among the zooplankton. By pooling the broad range of sites sampled in each transect, results indicated that total zooplankton densities decreased with increasing distance downstream. Copepods such as the cyclopoid *Mesocyclops* and *Thermocyclops* and particularly the *T. neglectus* registered the highest areal densities (100 ind.m^{-2}), followed by the rotifers (e.g. *Asplanchna*, *Brachionus* and *Euclanis*). Large macro-benthic organisms such *Caridina nilotica* (freshwater prawns), Ostracods and larvae of chaoborid and chironomid flies were also encountered among zooplankton samples, indicating regular appearances in the water column. Cyclopoid copepods and rotifers were consistently the most diverse groups throughout the study.

Throughout the study, it was observed that those areas with strong water currents e.g the sampled mid Kirindi section supported lower species diversity and abundance compared to the calm sheltered areas at Kalange and Buyala. The stable environments at Kalange and Buyala provide greater food availability and less physical disturbance allowing the zooplankton community to thrive. Such conditions are likely to promote high food consumption and, subsequently, a high turnover of zooplankton populations compared with those observed elsewhere (Bakker & van Rijswijk (1994).

3.4. Macro-Invertebrates

Macro-invertebrates are a vital component of the aquatic ecosystem's food webs. As elements of the detritus food chain, they break down dead organic matter into inorganic forms and thereby reduce the rate of accumulation of materials on the river's bottom. They are a major link between primary producers and consumers as well as being food for fish. The higher the abundance and diversity of macro-invertebrates, the wider the niche width for fish and less inter- and intra-specific competition for food resources. In Lake Victoria, Corbet (1961) observed that all fish in the lake basin including rivers feed on invertebrates at some stage in their lifecycles. As a result, the fisheries are dependent on the abundance and diversity of the macro-invertebrates as they are a major food source for fish.

There were no clear trends in macro-invertebrate diversity and abundance from upstream to downstream nor any apparent seasonal patterns. The seasons had little impact on species diversity and abundance at any of the four transects. Consequently, the changes in species diversity and abundance may have been due to lifecycle processes as opposed to external influences.

The orders: Diptera, Tricoptera, Gastropoda and Bivalvia had the highest number of genera throughout the four sampling periods. However, their abundance and diversity were not seasonally or spatially related. The molluscs were the most diverse group of macro-invertebrates and consisted of 10 and 8 genera during quarters 3 and 4 respectively. The dominance of benthic macro-invertebrates in the Upper Victoria Nile is similar to that of lakes Victoria and Kyoga. In these lakes, introduction of the Nile perch resulted in the decimation of molluscivorous fish, which could have allowed the molluscs to flourish.

Several species were abundant throughout all four surveys. The *Bellamya* sp. (Gastopoda) recorded the greatest species density (3,233 ind.m^{-2}) and consistently recorded the highest density for all four surveys. Other abundant species included the *Ephemeralla sp.*, may fly, (Order Ephemeroptera) and the *Corbicula sp.* and *Caelatura sp.* (Order Bivalvia).

The quarterly surveys of the Upper Victoria Nile revealed neither clear spatial nor seasonal patterns. However, considering the key taxa, both seasonal and spatial trends could have been discovered with additional sampling. The recognised key taxa were: gastropods (*Bellamya, Gabbia, Melanoides*) and bivalves (*Corbicula, Coelatura* and *Byssonodonta*) among the molluscs; and among the Diptera the key taxa were *chironomus, Povilla* and *Ephemaralla*. The Tricoptera and Odonata, though important dietary items in fish stomachs, were represented by a few genera and were only recognised as being present.

The key gastropod genera (*Bellamya, Gabbia* and *Melanoides*) registered the highest densities (3233, 2022, 490 ind.m^{-2} respectively) in transect 1 during the second quarter (long rainy season). *Bellamya* was also the dominant gastropod (827ind.m^{-2}) during the fourth quarter (short rainy season). Conversely the key bivalve genera (*Corbicula, Coelatura, Byssanodonta*) had peak abundances during dry seasons, especially at transect 2. The long dry season (first quarter) densities of *Corbicula* (202ind. m-^{2}) *Coelatura* (58 ind. m^{-2}) and *Byssanodonta* (112 ind. m^{-2}) were generally less remarkable in comparison to the short dry season when *Coelatura* (1851 ind. m^{-2}) was the most abundant of all molluscs in this transect. Although not featuring among the more common molluscs, bilharzia causing molluscs, *Bulinus* and *Biamphlaria* were also encountered in both upstream and downstream transects.

The *Chironomus* (order: Diptera, lake fly), *Povilla* and *Ephemaralla*, the may fly (Order: Ephemeroptera) were the most important aquatic insect taxa as well as common food for fish. *Chironomus* density had a decreasing seasonal trend even though the first two quarters differed in weather conditions. The first two quarters at transect 1 supported the highest densities, 1567 and 1165 ind. m^{-2} respectively, decreasing to 182 ind. m^{-2} during the third quarter and to zero counts in the fourth quarter. Ephemeroptera showed two prominent peaks, one during the second quarter (1134 ind.m^{-2}) at transect 1, and the second peak at transect 3 (575 ind. m^{-2}) during the third quarter. In general, transect 4 supported the lowest macro-invertebrate densities with only traces of aquatic insects during the first quarter.

The dominance of molluscs during the four surveys may result in potential health implications. Specifically, if a reservoir is created as a result of the hydro-electric plant, the abundance of the reservoir molluscs should be monitored. The risk of infection by bilharzias will be increased if these macro-invertebrates flourish. Of particular relevance was the occurrence of both *Bulinus* and *Biomphlaria* bilharzia snails in upstream transects. As the transects will contain the reservoir, a change from the mostly flowing habitat zone to one which will have a slower-flowing regime over a much widened habitat could result into suitable conditions for an increase in snail density. Moreover, this will be the zone to attract accumulation of weeds e.g water hyacinth with which molluscs in general are associated.

Laboratory analyses of the Upper Victoria Nile fishes confirmed that juveniles of *L. niloticus* depend on invertebrates during their early stages of development and others like *Rastrineobola argentea* (Mukene) and *Mormyrus kannume* depend on invertebrates throughout their lives. Should the hydro-electric plant restrict water flow and decrease water levels, then the macro-invertebrates could experience a reduction in habitat. With less flowing water, the macro-invertebrates will be in competition for habitat and their abundance and diversity will decline. As a result, the fisheries will be impacted, as they would be losing a prime food source.

4. The Fisheries

Over 30 fish species belonging to 11 families were found in the study area (Table 1). The family Cichlidae contained the highest number of species. This family contains two distinct categories of fishes referred to as haplochromines and tilapiines.

Table1: Overview of the fishes recorded during the four surveys of the four sampling stations of the Upper Victoria Nile (Feb-Dec 2000)

FAMILY	Scientific Name	Common English name	Local name
BAGRIDAE	*Bagrus docmak*	Cat fish	Semutundu
CYPRINIDAE	*Barbus altianalis*	Barbel	Kisinja
	Labeo victorianus	Barbel	Ningu
	Rastrineobola argentea	Minnow	Mukene/Omena /Dagaa
	Brycinus jacksonii	Barbel	Nsoga
	Brycinus sadleri	Barbel	Nsoga
MORMYRIDAE	*Gnathonemus victoriae*	Elephant snout fish	Kisomma/Bobo
	Mormyrus kannume	Elephant snout fish	Kasulubana/Kasulu/Menya Kasamene
	Mormyrus macrocephalus	Elephant snout fish	Kasulu/Nsulusa/Ngolobo Menya
	Gnathonemus longibarbis	Elephant snout fish	Kasulu/Mpumbi Nkoiro
	Petrocephalus catastoma		Kisoma
	Marcusenius grahami		Kasulu
CICHLIDAE	*Haplochromis*	Haplochromines	Nkejje
	Astatotilapia	Haplochromines	Nkejje
	Astatoreochromis	Haplochromines	Nkejje
	Macropleurodus	Haplochromines	Nkejje
	Platyaeniodus	Haplochromines	Nkejje
	Haplotilapia	Haplochromines	Nkejje
	Lithochromis	Haplochromines	Nkejje
	Neochromis	Haplochromines	Mbipi
	Ptyochromis	Haplochromines	Mbipi
	Yssichromis	Haplochromines	Mbipi
	pundamilia	Haplochromines	Mbipi
	Paralabidochromis	Haplochromines	Mbipi
	Psammochromis	Haplochromines	Mbipi
	Oreochromis leucostictus	Tilapia	Ngege
	Oreochromis niloticus	Tilapia	Ngege
	Oreochromis variabilis	Tilapia	Mbiru
	Tilapia zillii	Tilapia	Ngege
LEPIDOSIRANIDAE	*Protopterus aethiopicus*	African lung fish	Mamba
CLARIIDAE	*Clarias gariepinus*	Cat fish	Male
CENTROPOMIDAE	*Lates niloticus*	Nile perch	Guru/Mputa
SCHILBEIDAE	*Schilbe intermedius*	Butter fish/Silver fish	Olive Nzere
MOCHOKIDAE	*Synodontis afrofischeri*	Catfish	Nkolongo
	Synodontis victoriae	Catfish	Nkolongo

Haplochromines were until recently referred to under a single genus "*Haplochromis*". Similarly, tilapiines were assumed to belong to a single genus "*Tilapia*". In taxonomic terms of relevance to biodiversity issues, reappraisal of the *Haplochromis* generic concept has been undertaken in a series of studies (e.g. Greenwood, 1974, 1981, Strauss, 1984; Kaufman, 1997; Witte *et al.* 1997; and Seehaunsen, 1998). As a result, the number of *Haplochromis* genera has been reduced from previous estimates (300+ species) to five, and the number of "*Haplochromis*-like" genera (e.g *Astatoreochromis*) have increased to at least 20.

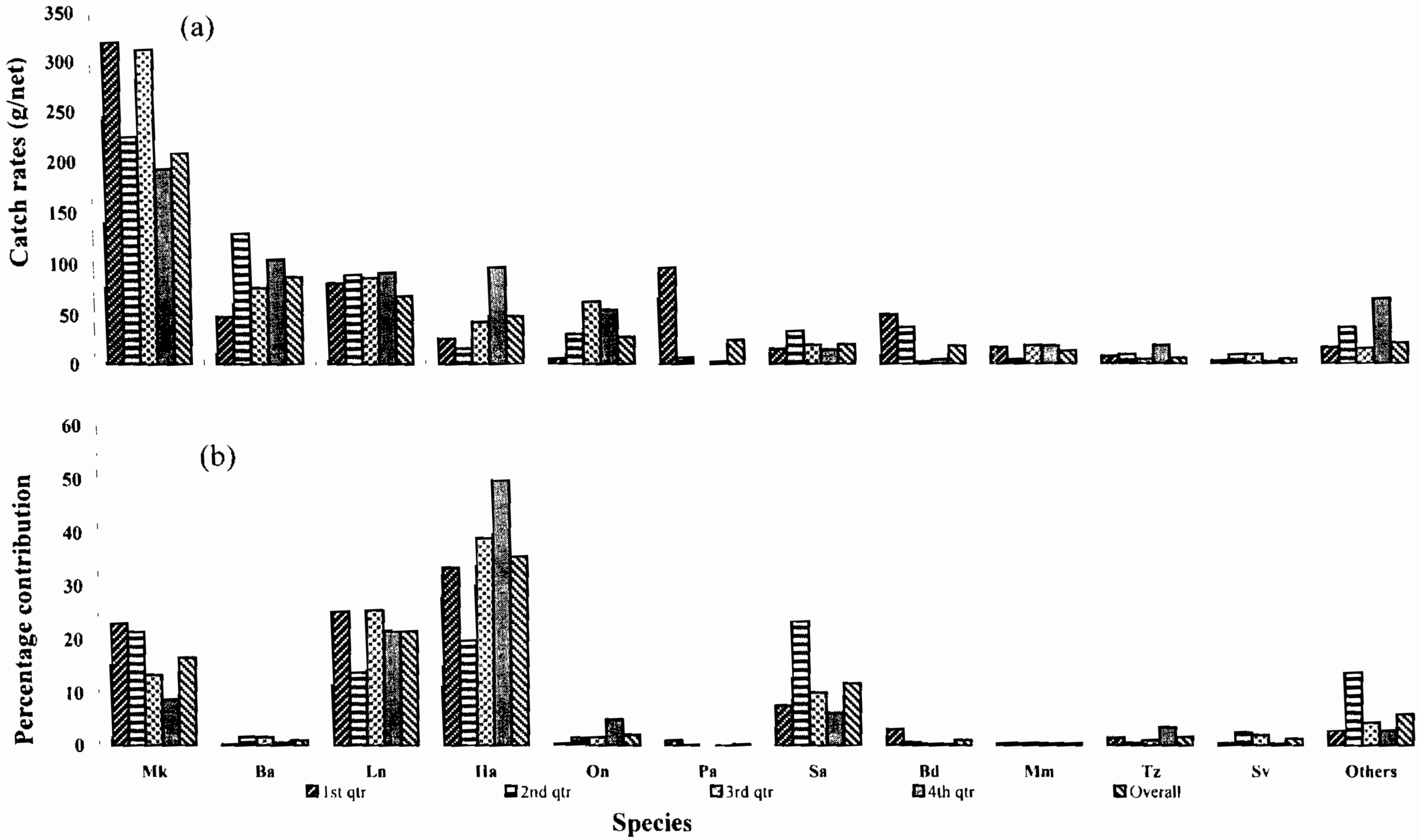


Fig 4. (a) Relative abundance (catch rates) percentage distribution (b) of different fish species caught during the four quarters of the year 2000 along the Upper Victoria Nile.

Mk - *Mormyrus kannume*
Ba - *Barbus altianalis*
Ha - *Haplochromines*
Ln - *Lates niloticus*
On - *Oreochromis niloticus*
Pa -*Protopterus aethiopicus*
Sa - *Synodontis afrofisheri*
Bd - *Bagrus docmak*
Mm- *Mormyrus macrocephalus*
Tz - *Tilapia zillii*
Sv -*Synodontis victoriae*

With these revisions, species names have either changed or "unidentified" species are being allotted "descriptor" labels. These *Haplochromis*-like genera (e.g. *Macropleurodus, Platytoeniodus, Haplotilapia, Lithochromis, Neochromis, Ptyochromis, Yssichromis, Pundamilia*, etc) and those species that were retained under the genus *Haplochromis* are collectively referred to as haplochromine fishes. In the four surveys of the Upper Victoria Nile, the following haplochromine species were identified: *Haplochromis* "Orange fin", *Haplochromis* "black", *Haplochromis* 20422, and *Haplochromis* "red anal". Other haplochromine genera encountered were: *Astatoreochromis, Astatotilapia, Harpagochromis, Lithochromis, Mbipia, Neochromis, Paralabidochromis, Psammochromis, Ptyochromis* and *Pundamilia,* hence, the 11 genera.

Similarly, for tilapiine fishes, the genus *Tilapia* has been redifined (Trewavas, 1983). It now includes the following genera: *Tilapia, sarotherodon, Oreochromis* and *Danakilia*. In the surveys of the Upper Victoria Nile, the following tilapiine species were found: *Tilapia zillii, Oreochromis niloticus, Oreochromis variabilis,* and *Oreochromis leucostictus*. The most dominant tilapiine (in numbers and biomass) from both experimental and commercial catches was *Oreochromis niloticus*. Juvenile tilapiines were also predominantly *Oreochromis niloticus*. However, *Tilapia zillii* was locally abundant especially at transect 2 (Buyala) during the first quarter.

4.1 Catch composition and Relative abundance (biomass)

Figure 5 shows catch rates (a measure of biomass) and contribution of fish species caught over the four quarters along the four transects. The category "*Others*" is comprised of species whose catch rates were less than 1g per net. These were: *Brycinus sadleri, Oreochromis leucostictus, Oreochromis variabilis, Clarias gariepinus, Labeo victorianus, Marcusenius grahami, Petrocephalus catastoma, Gnathonemus longibarbis, Gnathonemus victoriae* and *Schilbe intermedius*. A total of twenty-four (haplochromines included as a single species group) fish species belonging to seventeen genera in eleven families were recorded over the sampling period. By the third quarter all the species encountered had been recovered. Namasagali recorded the highest number of fish species, 17, while Kalange yielded 14 and Buyala and Kirindi each yielded 9 species. Biomass, as indicated by catch per net per night, was highest at Kalange (786.9g) and lowest at Namasagali (440.9). Buyala and Kirindi recorded 689.9 and 764.3g respectively. Statistical analysis (ANOVA) showed that there was no significant difference in catch rates between Kalange, Buyala and Kirindi but the difference between these three transects and Namasagali was significant (Table 2).

Table 2. p values for multiple comparisons of catch/net (biomass) at the four transect along the Upper Victoria Nile.

	Buyala	Kirindi	Namasagali
Kalange	0.993	0.366	0.029*
Buyala		0.377	0.031*
Kirindi			0.003*

Mean difference significant at the 0.05 level

In terms of biomass, fish species supporting the artisanal fishery on the Upper Victoria Nile were the most important. These were, in order of importance: *Mormyrus kannume*, *Barbus altianalis*, *L. niloticus*, the haplochromines and *Oreochromis niloticus*. Haplochromines, *Lates niloticus*, *M. kannume* and *Synodontis afrofischeri* were however, in that order, the most numerous species. The two exotic species, *L. niloticus* and *O. niloticus*, were common at all the transects.

Most haplochromines caught, especially at the first three upstream transects, belonged to the rock dwelling species flock known as the "Mbipi" (Seehausen *et al.*, 1998). These transects are characterized by fast running waters and rocky shoreline habitats. A total of twenty-six haplochromine species belonging to eleven genera were identified from the four transects. Kalange had the highest haplochromine variety (11 species from eight genera) while Kirindi recovered the least variety (five species from two genera). The Mbipi of genus *Neochromis*, *Pundamilia* and *Ptyochromis sauvagei* were the most common haplochromines at these sites consisting of 68.7% of the total haplochromine catches. Other rock dwellers recovered were *"Mbipi"*, *Lithochromis spp.* and *Paralabidochromis rock cribensis*. At Namasagali the haplochromines consisted mainly of the Lake Kyoga flock. These were *Paralabidochromis "blackpara"*, *Psammochromis "shovelmouth"* and *Astatotilapia "Kyoga astato"*. Names in parenthesis (" ") are cheironyms of yet undescribed species as named by "The Lake Victoria Research Team".

4.2 Fish zones and Keystone species

The Upper Victoria Nile as sampled between Kalange and Namasagali can be categorized into two main fish zones:

The river between Kalange and Kirindi

Fast flowing water, numerous river Islands and a predominantly rocky shoreline characterize this area. The rocks cover most of the river bottom and occasionally small rocky islands crop out of the water.

Fish species composition in this area was dominated by species that live in fast flowing waters such as *B. altianalis*, and rock dwelling species *M. kannume* and the "Mbipi" haplochromines. Though not among the dominant species, adult and young *B. docmak* also commonly occurred in this zone. The association between rock crevices and the haplochromines was noted. This zone therefore contains habitats, which provide some fishes with refuge from likely predators such as the Nile perch and fish otters (Seehausen *et al.*, 1998). Other keystone species (*L. niloticus, O. niloticus, L. victorianus*) were also recorded in this zone.

The river below Namasagali

In this zone, the river is slower, there are no rapids and the shoreline is covered with papyrus swamp. Being close to Lake Kyoga, fish species in this section are mainly the riverine and anadromous species from Lake Kyoga which include *S. afrofischeri, S. victoriae* and *M. macrocephalus*. *Oreochromis niloticus* and *L. niloticus* that dominate the Lake Kyoga artisanal fishery are abundant here.

Fish species that form the basis of the artisanal fishery in the river can be considered keystone species. These are *B. altianalis, M. kannume* and *B. docmak*. These are some of the species that were once abundant in Lake Victoria and are now experiencing a decline in their populations due to over-fishing and predation by the Nile perch. Biomass of these fishes has been established (Fig. 4). A change in numbers and biomass of these fish species during or after construction of the dam will be attributed to this anthropogenic activity. In addition, a change in water level up or downstream of the dam is likely to affect a number of haplochromine species. Different "Mbipi" species occur at different depth levels within the rock habitats (Seehausen *et al.* 1998). Water level changes may therefore lead to habitat disturbances. Particular attention is drawn to one haplochromine species: *Neochromis simotes*. This rock dwelling species has only been caught in this section of the Nile (Seehausen *et al.* op. cit.) Prior to this study only four specimens were available which are stored at the British Museum of Natural History. Three other specimens were recovered from Kirindi during this study. This species stands the risk of elimination if its habitat in the Upper Victoria Nile is greatly altered. It therefore deserves protection as it is not known whether or not it occurs in several other stretches of the Upper Victoria Nile.

4.3 Fish Ecology

Although multiple comparisons by ANOVA provided significant spatial differences in fish densities between the first three transects and the last transect (4), seasonal patterns were highly variable. In terms of biomass of fish, analyses (experimental and catch surveys) of the four surveys revealed that the part of the Victoria Nile upstream of the proposed project site, Kalange, (i.e transect 1) was the most productive but had the same species assemblages as transects 2 and 3. However, the part of the surveyed Upper Victoria Nile furthest away from the proposed project site, Transect 4, contained the highest fish species diversity (17 versus 9 to 14 at other sites) most of which are related to the Lake Kyoga fish stock. Transect 4 was removed from the upstream fish zone and potential cascading effects of the project on the section between transect 3 and 4 can only be clarified with one or two transects incorporated during the construction phase. Therefore, from socio-economic and conservation interests, it is the section between transects 1 and 3 that merits mitigation measures.

The surveys have revealed five keystone species: *B. altianalis*, *M. kannume*, *B. docmak*, *L. niloticus* and *Oreochromis niloticus*. The rock-dwelling "mbipi" haplochromines as well as some species associated with anodromesis (e.g *S. afrofisheri*, *S. victoriae*, and *M. macrocephalus)* between Lake Kyoga and Namasagali were also recogonised as keystone species with respect to ecological conservation. The two introduced species, *L. niloticus* and *O. niloticus,* were collected at all the investigated transects and appear to be the most evenly distributed species in the surveyed section of the Upper Victoria Nile. Two broad types of fish habitats could be discerned: the fast flowing rocky zone and the slower flowing zone. These zones have been characterised as follows:

The fast flowing zone habitats:
This is the section of the Upper Victoria Nile between the first transect, Kalange, and the third transect, Kirindi. It has steep slopes, a predominantly rocky shoreline and contains several rocky islands. The river bottom is also rocky with some outcrops resulting in rapids and falls. The most prominent of these are the Bujagali Falls, the Kalagala and the falls around Kirindi (i.e transect 3).

The slower flowing zone habitats:
The section of the Upper Victoria Nile about ten kilometers upstream of transect 4 at Namasagali and stretching downstream towards Lake Kyoga has a more uniform flow and occupies a wide valley characterized by floodplain features. The riverbanks are densely vegetated with papyrus (*Cyperus papyrus*). There are fewer rocky outcrops and the riverbed consists of mud and sand patches.

Shallow macrophyte-dominated calm habitats:
Diverse macrophyte strips of varying width line the riverbanks of these habitats. There are additional finer topographic features, between transect 1 and transect 3, (e.g. indentations) which create embayments similar in structure to the smaller bays typical of Lakes Victoria and Kyoga. In several locations, there were gaps in the macrophytes strips resulting from shallow water habitats, less than one meter deep, over sand, gravel or rock substrates.

4.4 Trophic interactions

The most common food ingested by the fish communities in the Upper Victoria Nile were the invertebrates, especially the insects including: Trichoptera, Ephemeroptera and chironomids (Figure 5). These were important food sources during the first and second quarters. Odonata was comparatively more

... and plant material (including periphyton), a pattern shared with immature *R. argentea*. Juvenile Nile perch (<15 cm TL), like the adults, were piscivorous but included more *Caridina* shrimps in their diet.

4.5 Key habitat interactions

The two broad habitat classes can further be sub-divided based on structural (e.g current speed, rocks, channel width and bank morphology) and functional (e.g. plant/macrophytes and prey items) attributes. For example, micro-habitat sub-zones within the fast flowing upstream sections include quieter areas in embayments, shallow narrow downstream stretches over rocky substrata, and mid-channel habitats in fast flowing water with or without rapids (Table 3).

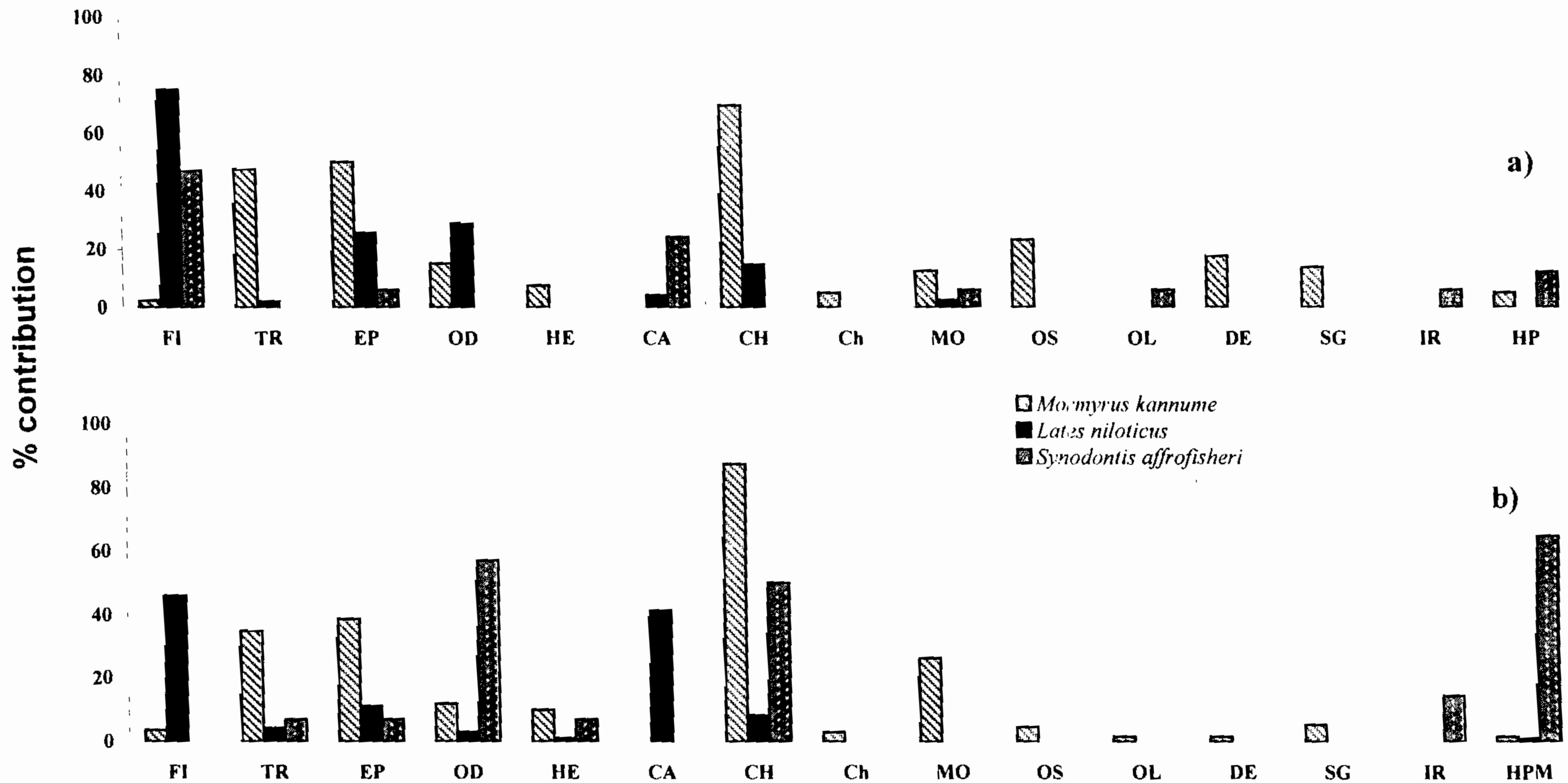


Fig.5 A Comparison of food types ingested by three keystone species of fish from the upper Victoria Nile. [a = dry season (February sampling) and b = wet season (October sampling)]

FI - Fish
TR- Tricoptera
EP- Ephemeroptera
OD- Odonata
HE- Hemiptera
CA- *Caridina*
CH- Chironomids
Ch- Chaoboorus
MO- Mollusks
OS- Ostracods
OL- Oligochaeta
DE- Detritus
SG- Sand grains
IR- Insect remains
HPM- High plant material

[illegible] (embayments) and back waters over generally mud and sandy bottoms and rocky patterns	habitats in fast current over hard bottom contained in steep slopes	rocky outcrops forming rapids	vegetation – (papyrus, reeds, crops) dominated banks and indications of flood-plain morphology	calm shallow water near boat landings occupied by macrophyte beds
O. niloticus *M. kannume* *R. argentea* Haplochromines	*L. niloticus* *M. kannume* *B. altianalis* Haplochromines	*B. altianalis* *B. docmak* *L. niloticus* *M. kannume*	*S.* afrofisheri *S. victoriae* *O. niloticus* *M. macrocephalus* *L. niloticus*	Juvenile fish *O. niloticus* *L. niloticus* *R. argentea*

In the preceding scheme, it was recognized that samples of fish populations from the surveyed area of the Upper Victoria Nile fall into two major communities: those that are related to the Lake Victoria basin and occur in transects 1 to 3 and those that are related to and show strong anadromesis towards Lake Kyoga. Both surveys and literature indicate that the fish populations in the upstream habitats (Transect 1 to 3) appear to be more closely related to the Lake Victoria fish stock prior to fish stockings in that lake. The fish populations at transect 4, Namasagali, are closely related to the fish stocks in Lake Kyoga. Results of all completed research suggest that the fish species at transects 1 to 3 are adapted to fast flowing water habitats and are separated from downstream slow-flowing water habitats. The proposed project site is located within the upstream habitats of transects 1 to 3 which appear to be dominated by a continuum of fish adapted to the described habitat conditions.

Some fish populations have been divided into separate populations due to the magnitude (height) of various rapids that create a natural barrier. However, natural barriers need not necessarily be falls or rapids. It could be a change in velocity as occurs in the Upper Victoria Nile from transects 1-3 (Kalange-Kirindi) to transect 4 (Namasagali stretch). Other potential barriers are probably associated with riverbed characteristics, distance from breeding grounds, a change in riparian vegetation or differences in water quality. Therefore, with the exception of barriers such as the Murchison Falls which separate the Victorian column), macro-invertebrates (molluscs, insect larvae, *Caridina* – mostly benthic taxa), and some insects found in root mats and young fish. Other sources of food were attached algae (periphyton), organisms living in decomposing plant tissues (*Povilla* and *Ephemeralla*) and those associated with rock surfaces including both plants (epiphyton) and invertebrates (aufwuchs). At the Namasagali transect, terrestrial insects (ants) were a major allochthonous (external source) food item for *S. afro-fischerii*.

Several trophic groups were discerned based on stomach content analyses. The **Piscivourous species** are key predators and feed primarily on fish prey. The Nile perch and *B. docmak*, both piscvourous species, occupied the fast flowing deeper sections of the river. The fish prey comprised mostly young fish (*Rastrineobola*, haplochromines and tilapiines) that inhabited the vegetated river margins and calm shallow water near boat landings. Other trophic groups, such as the insectivore and detritivore species, which include mormyrids, cyprinids and tilapiines, also frequent this habitat for feeding on insects and detrital material respectively. Insectivourous species were *M. kannume* and several other mormyrids. The rock-frequenting group of haplochromines are described as rock scrapers feeding off aufwuchs.

4.8 The socio-economic importance of the fishery

The important fishery on the upper Victoria Nile consisted of *O. niloticus* (42.7%), *R. argentea* (20.1%), *M. kannume* (11%) and *L. niloticus* 10.6% (Table 4).

Table 4. Overall quarterly and annual percentage (weight) exploitation of the fishery resource along the four transects of the Upper Victoria Nile.

Species	Quarters (Year 2000)				
	Q.1	Q.2	Q.3	Q.4	Overall
O. niloticus	50.7	53.2	34.9	35.4	42.7
O.leucostictus	0.3	1.4	0.1	0.1	0.5
O.variabilis	1.7	4.3	0.8	0.2	1.7
O.rendallii	0.0	0.0	0.2	0.1	0.1
T.zilli	4.2	3.3	4.6	0.7	2.1
L.niloticus	14.1	13.5	20.8	0.8	10.6
M.kannume	14.2	13.6	16.9	3.4	11.0
B.altianalis	4.7	5.7	8.8	1.3	4.5
B.docmak	9.7	2.4	6.2	1.9	4.5
P.aethiopicus	0	1.9	2.6	0	0.9
C.gariepinus	0	0.8	4.1	1.2	1.3
Haplochromines	0	0	0.1	0.1	0.1
R.argentea	0	0	0	54.7	20.1
L.victorianus	0.5	0	0	0	<0.1
G.longibarbis	0.01	0	0	0	<0.1

R. argentea was only prominent in the fourth quarter at transect 2 as the fishermen who had been drying the fish on the Islands had moved to the rocks on the mainland at transect 2 (Table 5).

Table 5. Percentage distribution by weight of different commercial fish species at the four sampling stations of the Upper Victoria Nile (2000)

Species	Transects				
	1	2	3	4	Overall
O. niloticus	31.4	10.0	11.8	86.9	42.5
O.leucostictus	0.3	0.1	0.0	0.0	0.5
O.variabilis	4.6	0.9	0.0	0.0	1.8
O.rendallii	0.0	0.2	2.9	0.0	0.1
T.zilli	4.7	1.7	8.3	0.0	2.1
L.niloticus	17.5	10.6	1.8	4.2	10.6
M.kannume	28.1	5.7	0.0	0.7	11.0
B.altianalis	6.8	3.8	10.6	4.0	4.9
B.docmak	3.0	7.2	54.7	0.3	4.1
P.aethiopicus	2.7	0.0	0.0	0.0	0.9
C.gariepinus	0.6	0.4	0.0	2.9	1.3
Haplochromines	0.1	0.1	0.0	0.0	0.1
R.argentea	0.0	57.4	0.0	0.0	20.1
L.victorianus	<0.1	0.0	0.0	0.0	<0.1
G.longibarbis	<0.1	0.0	9.1	0.0	<0.1

The keystone species of the Upper Victoria Nile were determined based on their abundance at each of the transects over the four quarters. *O. niloticus* was the most dominant species at transect 4 followed by transect 1 while *M. kannume* and *L. niloticus* were dominant in transects 1 and 2 (Table 5). The same three species were the most dominant in first, second and third quarters with the exception of *R. argentea*, which dominated the fourth quarter followed by *O. niloticus* (Table 4). As a result, these are the four keystone species supporting the artisanal fishery on the Upper Victoria Nile.

Any major changes in the species distribution or abundance during dam construction will be attributed to the construction activities. Dam construction has been reported (Scudder *et al.*, 1985) to affect the variability of riverine fisheries. Welcomme (1979) noted that the productivity of the River Niger below the Kainji Dam fell by 50% between 1962-1969 after dam construction. The consequences of dam construction on the riverine fisheries have been documented world wide (Cowx *et al.*, 1998).

The size structures of the keystone species are shown in Figures 6, 7 (*O. niloticus, M. kannume,* and *L. niloticus)* and Figure 8 (*R. argentea)*. The major fishing gear at all transects consisted of hooks used in 69% of the sampled canoes (50% were used in angling canoes and 19% in longline canoes) Table 6. Hook fishing was conducted by 43-84% of the sampled canoes at transects 1 to 4. Other gears included: gillnets, used by 17.2% of the sampled canoes for mainly passive fishing, and cast nets, used by only 12.4%.

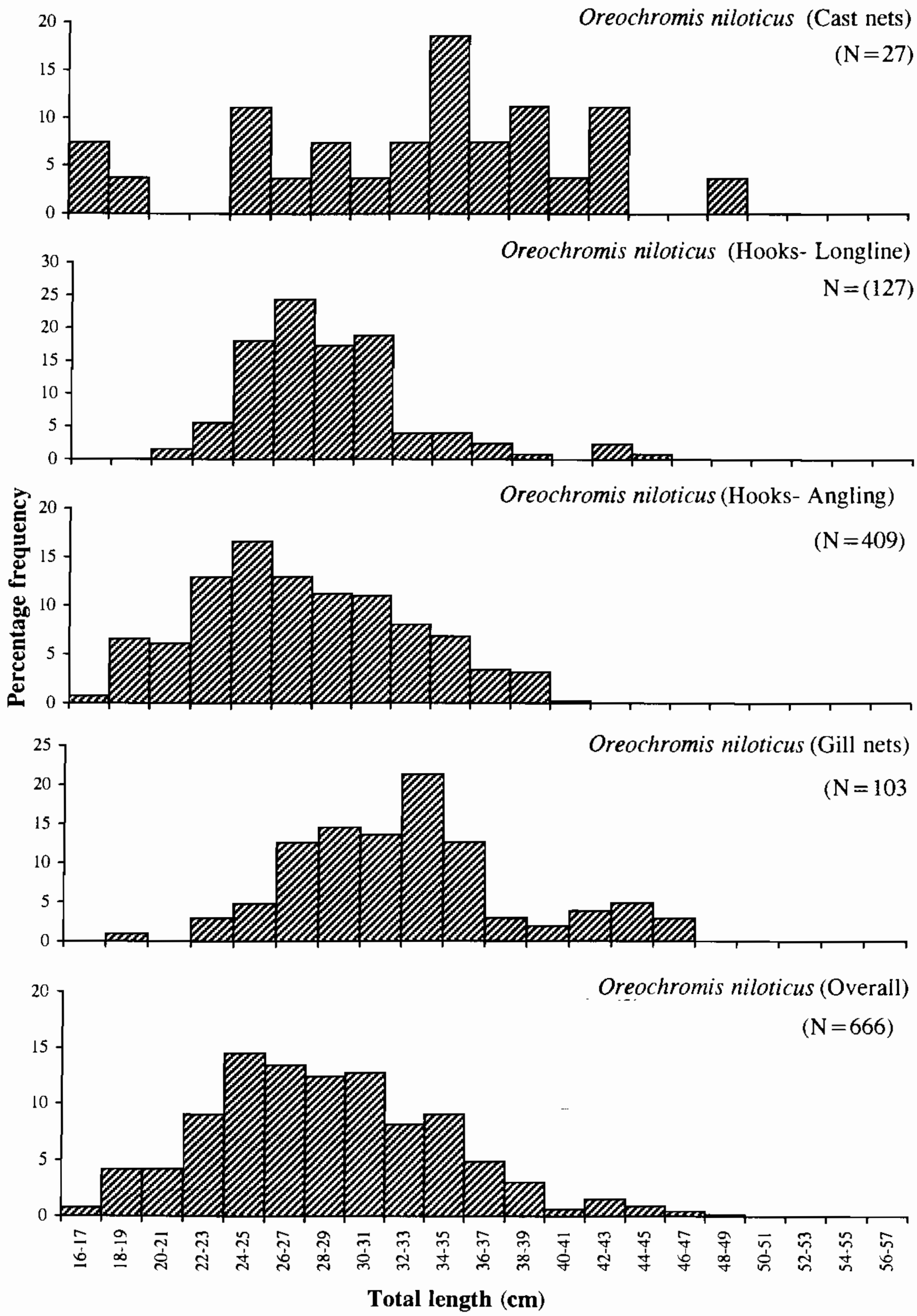


Fig.6 Size structure of *Oreochromis niloticus* caught by different gear and fishing methods from commercial catches at the four sampling stations of the Upper Victoria Nile (2000).

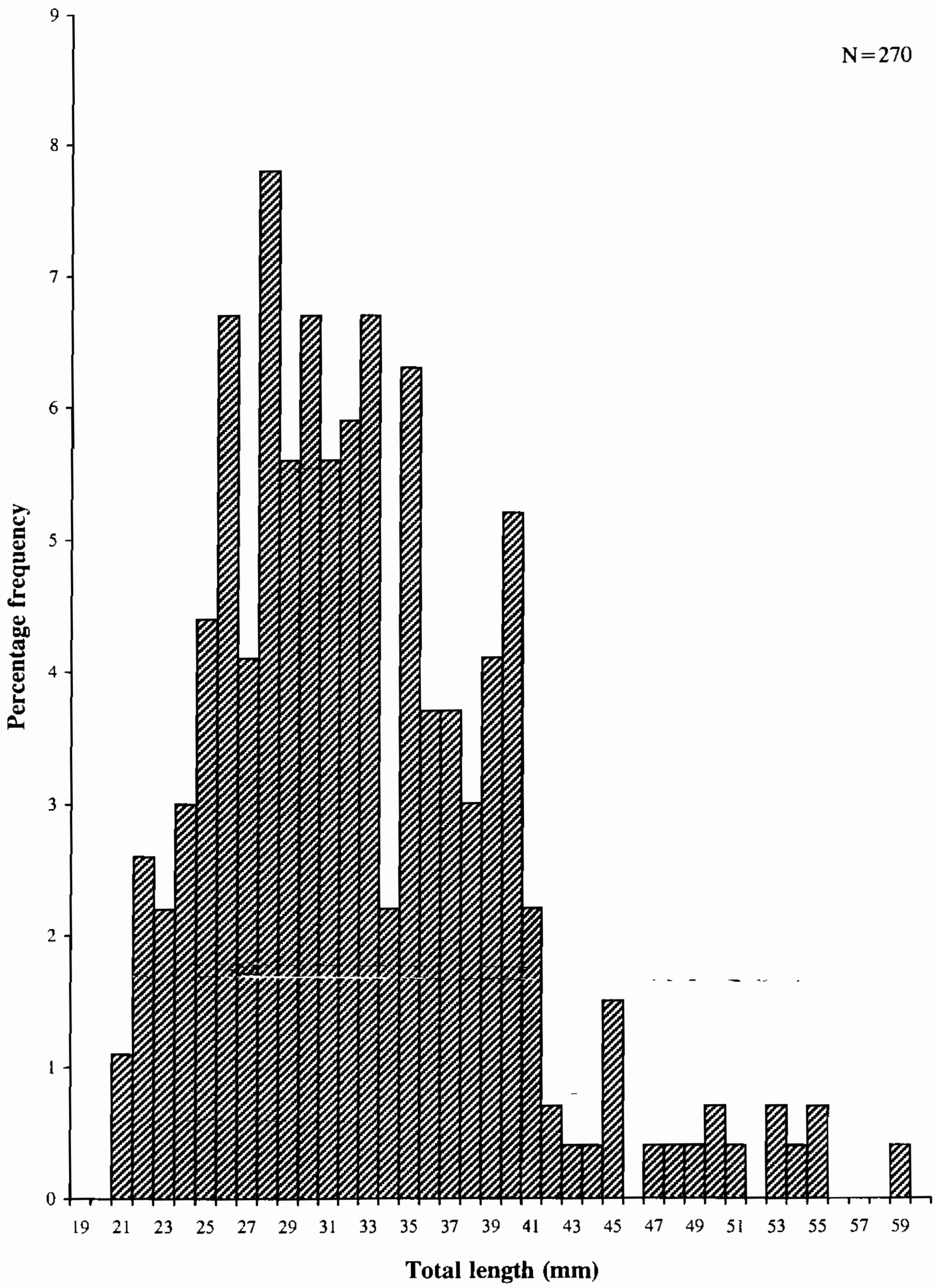


Fig.8 Length frequency distribution of *Rastreneobola argentea* caught by scoop net at Naminya transect 2 Downsteam of Dumbbell Island.

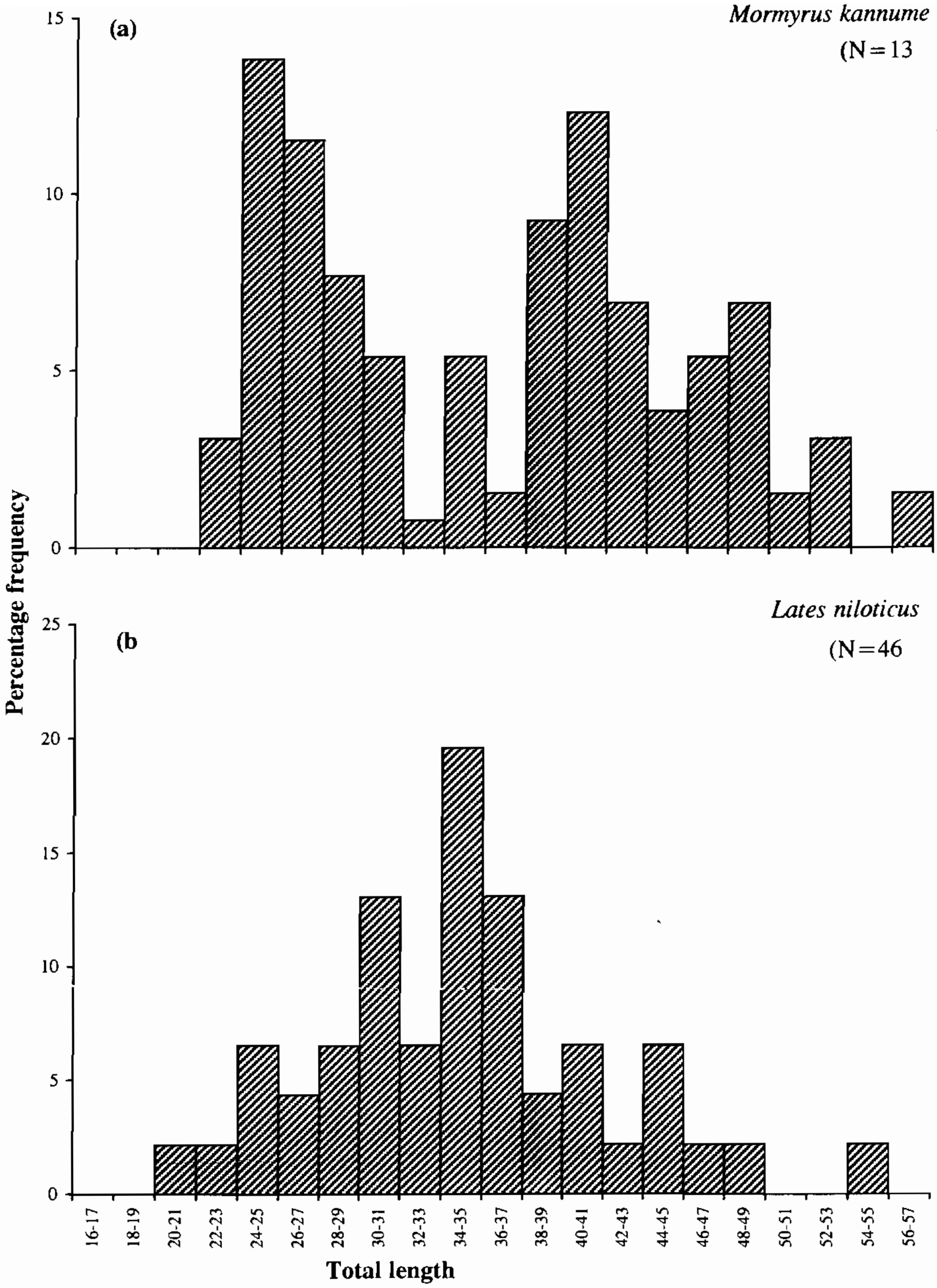


Fig.7 The overall size structure of (a) *Mormyrus kannume* and (b) *Lates niloticus* caught by different gear and fishing methods from commercial catches at the four sampling stations of the Upper Victoria Nile (2000).

Table 6. Percentage of fishing gears and fishing methods at the four sampling stations of the Upper Victoria Nile (2000)

Gear/fishing method	Transects				
Gillnets	1	2	3	4	Overall
Passive	21.2	17.5	6.7	9.2	12.9
Active	9.1		6.7	4.1	4.3
Castnets	27.3	20.0	20.0	3.1	12.4
Hooks					
Angling	27.3	42.5		67.3	49.5
Longline	15.2	15.0	60.0	16.3	19.3
Scoopnets		5.0			1.1
Traps			6.7		0.5

The highest overall catch per unit of effort (CPUE) (kg/canoe) was recorded at transect 1 (Kalange to Makwanzi) with a CPUE of 13.5 kg overall followed by transect 2 (Buyala to Kikuba Mutwe) with a CPUE of 13.2 kg overall(Table 7). The fourth quarter had the overall highest CPUE, 13.2 kg, due to *R. argentea* catches at transect 2.

Table 7. Mean CPUE (Catch kg/Canoe) at the four sampling stations of the Upper Victoria Nile (2000)

Quarters	Transect				
	1	2	3	4	Overall kg/canoe
1st quarter	16.6	6.8	1.8	2.6	5.6
2nd quarter	13.7	2.4	2.8	7.9	8.4
3rd quarter	12.6	11.1	0.0	2.3	6.3
4th quarter	7.9	27.1	0.0	7.8	13.2
Overall (kg/canoe)	13.5	13.2	1.1	5.3	8.2

Full time jobs of the Upper Victoria Nile (Table 8) included: boat-builders, food vendors, net repairers, fishermen, fish traders, chairmen of fish landings, fisheries extension staff, cleaners of fish landings, guards, Mukene dryers, and tax collectors. More people were employed during the dry seasons of February, first quarter (238 overall), and August, third quarter (231 overall), than the wet seasons of the second quarter (141 overall) and fourth (223 overall). The most overall man-days for full time jobs was noted at transect 2, where there are several fish landings, followed by a single landing (Namasagali) at transect 4. At transect 3, the fishermen went out fishing on the respective sampling days during the 3rd and 4th quarters but returned with no fish. It has been reported by the local residents and boat transporters between Kirindi and Matumu that there are constant changes in spatial water coverage within the Kirindi channel when it shrinks leaving about 20m wide river bed exposed for hours. This could be due to the effect of dam operations at the Owen falls dam farther upstream or downstream flow. This phenomena affects breeding grounds of fish and leads to decline in recruitment thus very low fish catch. Though this effect could not be verified as absence of fish catches on sampling days was noted during third and fourth quarters though very low catches were noted during first and second quarters in relation to other transects. Whatever the senerio, the fishermen will in the due course abandon the fish landing at Kirindi. The fishing activities have not been successful at transect 3 and have supported only a few jobs at the landing. As a result the food vendors also cater for passengers from transport boats. Despite the poor fisheries, fisheries staff, the chairman of the landing, boat builders and fishermen still operate at the landing as occasionally fish may be landed.

Table 8. The full time jobs supported by the fishery at the four sampling stations of the Upper Victoria Nile 2000.

Quarters	Transect				
	1	2	3	4	Overall
1st quarter	49	93	21	75	238
2nd quarter	38	28	15	60	141
3rd quarter	66	97	21	47	231
4th quarter	61	86	9	67	223
Man jobs	214	304	66	249	833

The estimated monthly quantities of fish and their respective value are shown in Table 9. Transect 1, upstream of the proposed hydropower plant at Dumbbell Island, landed an estimated 13.2 metric tones valued at 7.94 million Shillings. The second transect landed 35.5 metric tones valued at 16.3 million Shillings and transect 4 recorded 11.6 metric tones valued at 5.8 million Shillings. The lowest catches were recorded at transect 3. An overall total of 60.8 metric tones valued at 31.16 million Shillings were estimated for four months, with higher quantities expected during the dry seasons of first and third quarters though fourth quarter contribution was due to Mukene that had not been recorded before.

Table 9. The estimated quantity and value (in brackets) of the fishery (per month) in kilograms and millions of Uganda shillings at the four sampling stations of the Upper Victoria Nile (2000).

Quarters	Transect				
	1	2	3	4	Overall
1st quarter	3926.5 (2.37)	6057.2 (4.58)	255.0 (0.22)	955.2 (0.88)	11,193.9 (8.05)
2nd quarter	3421.7 (1.77)	602.0 (0.47)	308.0 (0.9)	3637.7 (1.74)	7,969.4 (4.88)
3rd quarter	3632.6 (2.31)	9155.3 (7.93)	0 (0)	845.3 (0.42)	13,633.2 (10.66)
4th quarter	2185.4 (1.49)	19,651.2 (3.28)	0 (0)	6,126.0 (2.8)	27,962.6 (7.57)
Total	13,166.2 (7.94)	35,465.7 (16.26)	565.0 (1.12)	11,564.2 (5.84)	60,759.1 (31.16)

5. Discussion

Macrohabitat characteristics

The Upper Victoria Nile water resources including the fisheries experience climatic seasonality mostly resulting from changes in rainfall, and to a smaller extent, temperature. The period December to March is regarded as the dry and hot season and the period from mid-March to end of June is the long wet season. July to mid-September is the short dry season followed by the short wet season from September to November. However, from trend analyses of over 50 years, it is known that the timing and duration of these seasons vary (Welcomme, 1966; Balirwa, 1998). Such variability could have masked some of the expected seasonally varying trends in physio-chemical and biological features of the Upper Victoria Nile. Moreover, the hydrology of the Upper Victoria Nile partly depends on that of Lake Victoria and partly on the regulatory regimes at the Owen Falls Dam (of the Agreed Curve) of which this study had little information. However, the daily flows of the Upper Victoria Nile (cumecs) at the Owen Falls Dam (upstream of the proposed project site) and further downstream site at Mbulamuti (in the vicinity of transect 4 at Namasagali) were compiled for 1998/99 and part of 2000 and were presented in the first quarter report. The data seem to suggest a seasonal discharge.

It was clear from the surveys that apart from the irregularity of flow due to falls and rapids, there is an overall change in the velocity characteristics of channel flow between Kalange, upstream of the project site, and Namasagali, the furthest downstream site sampled. The upstream sites are characterised by a more swift mid-channel current associated with falls and rapids such as at Bujagali and Kalagala. Further downstream the flow is more gentle and generally more uniform across the channel width especially at transect 4 (Namasagali).

The results also indicated that the water quality and biotic features varied longitudinally. For example, water transparency increased while suspended solids decreased with distance downstream. External factors, such as catchment derived nutrients and suspended solids due to agricultural practice, were elevated upstream (transect 1 to 3) as were phytoplankton densities. These observations indicate that sediment deposition downstream is rapid where flows fall below the critical erosive shear velocity. The phytoplankton production is sensitive to the nutrient inputs affecting the distribution and density of consumer trophic groups. As a consequence of increasing water clarity and reduced spread of current downstream, macrophyte development of papyrus swamps reached maximum density and lateral spread and the underwater flora consisted of obligate enhydrophytes such as the *Ceratophyllum* and *Pistia* due to flood-plain conditions at transect 4. This resulted in the highest macrophyte diversity despite the dominance of papyrus-dominated banks. Elsewhere, the importance of widespread but separated littoral macrophyte-dominated stretches (*Vossia, Eichhornia, Phragmites*) along the river banks could explain the diversity of habitats. These habitats provide temporal refuge to fishes that make diurnal excursions towards the banks for feeding, breeding and nursing. From the observations made elsewhere (Balirwa, 1998), the three species may be expected to withstand water level changes of up to one metre such as may occur in an impoundment.

Water weeds are a particular concern of the proposed hydropower project. The water hyacinth, regardless of its apparent reduction and control by the introduced weevils, remains a significant feature in the Upper Victoria Nile, as it is likely to resurge. The hyacinth would create problems in the impoundment associated with a dam and would accumulate and flourish irrespective of the dam's water retention time. Should this occur, hippo grass would also colonize the reservoir margins as it is closely related to the hyacinth. It is imperative that the weeds are controlled, using measures such as those at the Owen Falls Dam, as they impact the fisheries by reducing fish habitat.

Fish populations in the Upper Victoria Nile

On the basis of the studies carried out, the Upper Victoria Nile ecosystem can be divided into two zones, each with a characteristic fish population. River zonation is defined by structural (current, rocks/rapid, channel width, bottom types/substrates, topography) and functional biotic features (macrophytes and food organisms). These factors, in turn, influence the distribution of fishes in the two zones.

The upstream sites, between transects 1 and 3, (fast flowing zone habitat) are characterised by fishes (e.g. *L. niloticus, M. kannume, B. altianalis and B. docmak*) that either live or spend part of their lives in fast flowing water. These fishes are further adapted to the rocky nature of these habitats with morphological features such as a streamlined shape, a long thin caudal peduncle and barbels.

Prior to the 1950s, before widespread species stockings in Uganda's aquatic ecosystems, Nile perch and Nile tilapia were absent from the Victorian fauna. Unique species of the Victorian fauna included; *Oreochromis esculentus*, *O. variabilis*, *Labeo victorianus*, *B. altianalis* and *S. afrofischeri*. There are a few species, such as the *Clariallabes,* which are unique to the Victoria Nile and others like *Mormyrus macrocephalus* and *Xenoclarias* to Lake Kyoga and Lake Victoria respectively. Therefore, fishes which were found along the Upper Victoria Nile during the four surveys and those which have been reported as occurring in both lakes Victoria and Kyoga are typical Victorian fauna. However, this Victorian fauna comprises of populations (stocks) and sub-populations in different parts of the Lakes Victoria and Kyoga basins.

There were no significant differences in the abundance of these species between transect 1 and transect 3 and the fish populations of this zone differed from those further downstream. It is reasonable to suggest that transect 1 to 3 is a prime zone for the species. Therefore, an artificial barrier (dam) erected in this zone may subdivide the populations and impact on the migratory route of the fishes.

Some studies conducted in Europe and reported by Cowx & Welcomme (1998) provide insight into the impact barriers across rivers on fish populations, and, means of enhancing fish migration. These studies suggest the construction of barriers across rivers has had negative effects on natural fish populations contributing to the diminished abundance, disappearance and even extinction of species. The situation in the Upper Victoria Nile may require further study focusing on migratory aspects of the identified keystone species.

Several fish species among them the identified keystone species of the Upper Victoria Nile were till 1970/80s still abundant in lakes Victoria and Kyoga. The biology and ecology of these species (e.g *B. altianalis, L. victorianus, M. kannume* and *C. gariepinus*) has been summarised by Greenwood (1966). These species have been decimated from the lucustrine (lake) habitats through a combination of impacts such as predation and destructive fishing methods (Ogutu-Ohwayo, 1990) and environmental degradation (Balirwa, 1995). In sharp contrast to this state, the Upper Victoria Nile contains large stocks of these keystone species as was shown during the quarterly survey observations. Because of the enumerated potential of several barriers that separate populations (stocks) even within the Upper Victoria Nile, it may be considered that the stocks in the upstream part of the river are distinct from those in the open waters of Lake Victoria and those of Lake Kyoga. Although more solid evidence for geographical separation of the keystone species may be lacking, some studies carried out on other fishes in the lakes Victoria and Kyoga basins (e.g Mwanja, 2000) show genetic differentiation between macro-habitat zones. Therefore, one of the possibly major impacts of an artificial barrier in the river on fish populations in the direct impact zone (i.e. between transect 1 and transect 3), is to separate zones in which the fishes presently mix freely.

Fish sensitivity to environmental perturbations

In evaluating fish sensitivity to environmental perturbations in the Upper Victoria Nile, the consequences of the following examples of potential impacts directly due to the proposed project have been considered:

- Physical-chemical changes (e.g in dissolved oxygen, pH, conductivity, nutrients) particularly in reservoir;
- Discharge/retention time changes after the creation of an artificial barrier;
- Sediment load;
- Proliferation of aquatic weeds in the reservoir;
- Contraction or change in the dimensions of the morphology (lateral extent) and river bed characteristics (sediment deposition) of the river channel in the direct impact zone;

- Change in fish species (trophic cascades);
- Subsequence of vegetation, land lake impoundment of streams.

Table 10 summarizes the outcome of a ranking scheme for what are considered negative impacts.

Table 10. A ranking of potentially negative (-ve) impacts associated with the construction phase of the proposed Bujagali hydropower project on upstream (U) and downstream (D) aquatic related aspects of direct relevance to the fisheries

	Impact Level (+ve / -ve)					
	1		2		3	
Potential construction impacts	U	D	U	D	U	D
Sediment load				-ve	-ve	
Surface water quality					-ve	
Water volume				-ve		
Discharge	-ve	-ve				
Habitat			-ve			
Trophic interactions					-ve	
Longitudinal migrations			-ve			
Lateral migrations					-ve	
Spawning migrations					-ve	
Macrophytes						
Biodiversity			-ve			
Formation of impoundment-						
Siltation and deposition					-ve	
Turbidity					-ve	
Eutrophication					-ve	
Increased residence time			-ve			
Weeds (Macrophytes)					-ve	
Algal blooms					-ve	
Change in physical parameters			-ve	-ve		
Change in flow regime (Reservoir)			-ve	-ve	-ve	
Stablization of zooplankton						
Creation macro-invertebrate habitat						
Creation of new habitat						

U = Upstream (transects 1,2 and 3); D = Downstream (transect 4)

The recognised trophic interactions are: predators (piscivores), insectivores, zooplanktivores, rock scrapers, phytoplanktivores and detritivores. Although subjective, the three-point scale of assigning impact level on assumed aspects of importance to the fisheries may be considered as the entry point for monitoring

Depending on the influence of nutrients and ions released into the reservoir following inundation, changes in water quality could impact the new reservoir fisheries. Some species such as the Nile tilapia and *Clarias gariepinus* may dominate the reservoir stocks at the expense of other species such as the Nile perch and *Bagrus docmak* which are more vulnerable to changes in dissolved oxygen. For example, as a rule of thumb, dissolved oxygen concentrations below $4 mg.l^{-1}$ leads to fish kills. In the FIRRI aquaria, these two species do not survive below a threshold DO concentration of about $5.5 mg.l^{-1}$ whereas both Nile tilapia and *Clarias* do.

Weed proliferation (e.g. of water hyacinth), algal blooms, die-off of plants and their decomposition could reduce the oxygen content of the water, result into release of more nutrients and changes in pH to alkaline (pH>9.5) levels and an increase in the production of ammonia (NH_3) to potentially toxic levels. Most fishes would be sensitive to these changes.

The main effects downstream would be on the lateral spread of the water mass into embayments. It is not clear whether or not the barrier would reduce the amount of water that would have previously supported the feeding grounds of the fishes. If water level changes were to be manifested into a shrinkage of feeding habitats along the banks, the trophic structure of the fishes would also change.

Evidence for fish migration

The seasonal fish migrations in the fast flowing zone (transects 1 to 3) are dictated by fish breeding and feeding habits. Seasonal breeding migrations are longitudinal upstream while feeding migrations are lateral, towards the river banks. The occurrence of detrital material, higher plant remains, juvenile fish prey including *Rastrineobola argentea* and in some species of terrestrial insects provides evidence for fish feeding in the littorals along the river banks and its embayments. *M. kannume, B. altianalis, L. victorianus* are known potamodromous species that ascend rivers to breed (Cadwalladr, 1965, Okedi, 1970 & Welcomme, 1969). This was substantiated by the results of the four surveys which indicated that these species probably move upstream against the current (i.e. towards transect 1) for spawning on the Upper Victoria Nile.

Few studies have been completed which define the migratory habits of the fish in the Upper Victoria Nile. Unfortunately, a study was not conducted during the construction of the Owen Falls Dam that may have researched these fish migrations. Currently, no research on the fish migrations around Ripon Falls exists and, as a result, it is not known if the fish can ascend the now semi-submerged falls. Furthermore, there are other potential barriers, such as Kalagala and Bujagali Falls, whose effects on distribution patterns and fish behaviour have yet to be determined. However, taxonomic and zoogeographic studies reported by Greenwood (1966) and Beadle (1974), indicate that 'nilotic fauna', fishes of Lake Albert and the Albert Nile, are separated from the Victorian fauna by Murchison Falls. Upstream of this most prominent natural barrier, are species which are common through the Kyoga Nile, Lake Kyoga, the Upper Victoria Nile and Lake Victoria. Research by Greenwood (1966) and Beadle (1974) discusses the geographic differentiation of species into these two systems and evolutionary factors that account for the presence of some species in both geographic regions. Species that are common to both the Nilotic and Victorian systems include: *Bagrus docmak, Protopterus aethiopicus* and *Clarias gariepinnus*. Species which are unique to the Nilotic system include: *Hydrocynus vittasus*, *H. forskalii* (tiger fish), *Malapterus* (electric catfish) and *Distichodus niloticus*. All these species however, are not keystone species on the Upper Victoria Nile

Spawning of the fish populations in the Upper Victoria Nile has been deemed successful as ripe life females and young of the different species in the investigated river sections have been found. A major question then concerns the effectiveness of species separation by the natural barriers at Bujagali, Kalagala, Itanda, as compared to those of the Owen Falls Dam and other potential artificial barriers.

Spawning migrations in the Lake Victoria basin have been reported for several fish populations including those that were found in the Upper Victoria Nile. The species in this category were: *B. altianalis, L. victorianus, C. gariepinus, M. kannume, M. macrocephalus*, small sized Mormyrids and *Synodontis afrofischeri*. The majority of these species also occur in Lake Victoria from which they ascend in-flowing rivers and streams to breed (e.g Whitehead, 1959; Corbet, 1961; Cadwalladr, 1965; Greenwood, 1966; Welcomme, 1969; Balirwa, 1984. From these studies and observations on distribution and fecundity during the quarterly surveys, it is concluded that even within the Upper Victoria Nile, the species spawning migrations are to upstream habitats. After spawning, the fishes return to their feeding grounds.

Some other factors responsible for stimulating spawning migration, apart from the gonadal cycle of development, are: an increase in water volume related to the seasonal cycle of precipitation, an increase in electrical conductivity and turbidity due to an influx of dissolved substances. These triggers may bring about the onset of fish migration. That could be the basis of classifying the different species of this region into typically lacustrine, riverine or migrant fauna according to Corbet (1961). By this classification, the evolutionary sequence of adaptation by fish from riverine to lucustrine (lake) conditions can be evaluated with respect to the Upper Victoria Nile fishes. Corbet, (1961) suggested the following stages (with relevant species of the Upper Victoria Nile in brackets)

a) Feeding and breeding only in rivers (e.g stocks of *B. altianalis, L. victorianus, M. kannume* and possibly *B. docmak*);
b) Feeding in lakes and rivers, breeding only in rivers (e.g *S. afrofischeri* and *M. macrocephalus* between transect 4 and Lake Kyoga);
c) Feeding and breeding in lakes and rivers (some fishes in lakes Victoria and Kyoga);
d) Breeding and feeding in lakes (some fishes in Lakes Victoria and Kyoga).

Corbet (1960), considered wave-mashed rocky shores to constitute an important transition habitat able to accommodate the least adaptable stages in the life histories of those riverine fishes in the process of becoming lacustrine. Of the fishes occurring in the Upper Victoria Nile, *B. docmak* may fit this category as it was encountered mostly in rocky stretches (i.e upstream transects) of the sites sampled. This account clarifies the basis of recognizing the discussed barriers and distribution patterns of the fishes that were encountered in the Upper Victoria Nile.

It was clear from the quarterly surveys that the species discussed in relation to migration, were more common in the upstream transects, with the exception of *S. afrofischeri* and *M. macrocephalus* that were prevalent downstream. There are thus two principal seasonal migratory patterns:

- Within the river, where longitudinal upstream-downstream migrations take place. This pattern relates to transects 1 to 3 but it is not known what patterns may exist downstream of transect 3. The fishes associated with this pattern are *B. altianalis, L. victorianus* and *M. kannume*. If further insight of within the river upstream migrations beyond transect 3 were required, there would be need to study other sites between Kirindi and Namasagali.
- Out of Lake Kyoga, where fishes tend to migrate towards transects 4. The fishes associated with this pattern are *S. afrofischeri* and *M. macrocephalus*.

Potential mitigation measures

Geographical and geomorphological influences create changes in riverine environments, resulting in species separation and subsequent species sub-populations (Welcomme, 1985). The river zonation for the impacted area has been defined by the geomorphology of the region resulting in differing flow regimes and water chemistry. These two factors have divided the impacted area into two distinct zones: the fast flowing zone, transect 1,2, and 3, and the slower flowing zone, transect 4 to Lake Kyoga. Unique fish populations, living in the two discharge into this quarry once the surrounding area is vacated by the resident human population. The scenario would then present some of the migrating fishes (e.g. *Labeo victorianus*) with a migratory route from the river, through the quarry area into the streams.

- Within the quarry pit, there could be created rocky islands with provision for crevices that are partly submerged and have been shown to be colonised by the 'Mbipi' haplochromines.

It is considered that if these options were clearly understood in the early stages of the project execution, the identified habitats could actually be created and mitigate some of the potential impacts of impoundment.

In order to gain a better understanding of the potential implications of the proposed project, it has been identified that certain aspects of the biology and ecology of the Upper Victoria Nile will require further research and monitoring. These are summarised as follows:

- A hydrological model investigating water flows with and without the dam. In this analysis, the quantity and quality of water through the Victoria Nile up to Lake Kyoga would be depicted on the longitudinal and lateral axes. Water quality would be depicted in terms of sediment load between the Owen Falls Dam and downstream sites and would include the accumulation of sediment at the proposed site (Dumbbell Island).
- The feasibility of a fish pass to allow longitudinal migrations, breeding, and feeding of known migratory fishes should be ascertained.

It appears from observations reported that longitudinal migration of fish in the Upper Victoria Nile takes place. While not conclusive from the reported observations, available options (e.g. tagging and year round monitoring in a tag-release-receptive exercise in addition to the application/relevance of indigenous knowledge) were not used. Therefore, verifying the fish migration habitat in an environment such as the Victoria Nile with all the confounding affects of rapids and an already established barrier (Owen Falls Dam) further upstream is a complex activity. Not only are the riverside communities recently settled and rural, they hardly would understand the value of such an activity. There is therefore need to involve and sensitize the fishing communities towards the importance of a fish tagging-recovery programme of fishes should such an activity be required beyond the results of the study. In addition, it has to be printed out that experience with tagging fish in Lake Victoria shows that for a statistically significant recovery, hundreds of specimens of a particular species have to be tagged and genuine recoveries can take up to two years to provide meaningful insight into migratory behaviour.

- Because of the expected earth excavation in the project area, it is suspected that soil erosion (such as was manifested in seasonal water quality changes during the four quarterly surveys) could wash soil material into the river. If not properly disposed of, an increase in sediment load could have measurable consequences for water quality, particularly in the reservoir. There is therefore need to monitor water quality changes and the response of fish during the construction phase of the project.

- Several questions remain concerning the structure of fish populations in the vicinity of other potential barrier e.g Kalagala and other sections of the Upper Victoria Nile between transect 3 and transect 4. For example, it is not yet known whether or not the same fish assemblages as were found between transect 1 and transect 4 also occur in these uninvestigated sections. These sections could be included during construction phase.
- The scope of work reported in this document did not require that potential observed impacts be ranked nor that feasible mitigation measures be indicated. Even though these aspects have variously been hinted upon, it is recommended that clearer mitigation measures be suggested (where applicable) in reports covering the construction phase observations. Provision of aquatic monitoring and fisheries survey data services during the construction phase could be expanded so as to include a ranking of potential effects and proposed mitigation measures. The valuation of different potential impacts could be based on a 'very large negative – to-a very large positive impact' scale.

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Annex A. Terms of Reference for the provision of Baseline Aquatic Monitoring and Fisheries Survey

General

These ToR outlines the baseline monitoring that shall be carried out in order to provide the data necessary to assess impacts of the Bujagali Hydroelectric project on fisheries, habitat and water quality. The exercise is intended to fulfil the recommendations provided for in the Bujagali Hydroelectric Project Environmental Impact Statement (EIS) of March 1999.

The following Scope of Work and Services details the requirements for the pre-construction phase of the project. The Scope of Work and Services incorporates a monitoring and survey exercise that includes four surveys to be undertaken at transects upstream and downstream of Dumbbell Island during the pre-construction phase. It is recognised that additional monitoring will be specified and commissioned at a later date. This scope of work is limited to the first year of study.

Scope of Work and Services

To undertake a Baseline Aquatic Water Quality Monitoring exercise in Fisheries and Habitats Survey on the Upper Victoria Nile, that shall include but not necessarily be limited to:-

EIS Requirements: General

The EIS recommends the collection of monitoring data to cover:
1. Hydrology
2. Water quality
3. Indicators of productivity of lower trophic levels (invertebrates) including critical or keystone species
4. Fishes and fish populations
5. Human uses of these aquatic systems, particularly as food sources

In addition, macrophyte surveys are required in order to monitor habitat and food chain effects on fisheries

This scope of work specifies the requirements for each of these aspects.
a) Four (4) surveys are required, at three monthly intervals over one year prior to commencement of construction.
b) The study area should be large enough to encompass the major significant impact anticipated both upstream and downstream of the site at Dumbbell Island. A total of four transects: one upstream and three downstream of the construction site shall form the basis of the exercise.

c) The furthest downstream transect will be at the entrance of the Victoria Nile to lake Kyoga or at a location agreed with the client or his representative.
d) During the construction phase itself, it is recommended that sampling be carried out at a fourth downstream transect, rather than upstream of the hydropower facility. However, this will be the subject of another commission.
e) The survey transects chosen should be representative of the upper Victoria Nile as a whole.
f) At each transect, five sampling stations should be identified, to cover the full range of habitats available across the width of the river channel.

Requirements for the final report are outlined under each of the specified subject headings below. In addition a progress report will be required after each survey

Hydrology
Continuous monitoring of water levels (upstream and downstream of Owen falls) and flows is currently carried out by DWD and data to be obtained by AESNP. In the present survey, the following assessments for the Fisheries Research Institute to undertake have been agreed:

Water quality

Water quality determinants to be monitored are outline in the table below

Water Quality Surveys			
Determinant	Method of analysis	No. transects	Tot. samples/ Measurements / survey
Suspended solids	Filtration, drying at 105^{0}C	4	20
Nitrate-nitrogen	Colorimetric filtration immediately after collection	4	20
Ammonia-nitrogen	Colorimetric filtration immediately after collection	4	20
Orthophosphate (dissolved reactive phosphate	Colorimetric filtration immediately after collection	4	20
Total Nitrogen	Digestion and Colorimetric	4	20
Total Phosphorus	Digestion and Colorimetric	4	20
Chlorophyll a	Acetone or methanol extraction followed by spectrophotometry	4	20
Temperature	Digital probe:depth profiling at deepest site in each of four transects	4	4
Dissolved oxygen	DO meter:Depth profiling at deepest site in each of four transects	4	4
Oil & grease	Partition-gravimetric method	4	20

Invertebrates Surveys

The proposed approach for invertebrate's surveys is as follows:

a) Sampling of benthic invertebrates (using an 'Ekman' type grab where the nature of the riverbed allows);
b) Sampling of pelagic invertebrates using vertical net hauls;
c) Identification of invertebrates to species level and enumeration

Sampling should be carried out at the same frequency and stations as water quality surveys (see above). Reporting from consultant should be factual, to include:

a) Records of all species identified at each sampling site
b) Identification of any critical or keystone species (e.g. fish prey species) by which fish food availability may be assessed.
c) Statistically significant changes in critical or keystone species during the monitoring period, particularly baseline seasonal changes, and changes pre and post construction.

Fish Surveys

There are two aspects to this component of the monitoring programme: fish stock surveys and fish catch surveys

The general approach to fish surveys is as follows:

Fish stock surveys should be carried out using:
a) 24 - hour gillnet samples for adult fish
b) seine netting for juvenile fish

Surveys should be carried out at three monthly intervals for one year prior to commencement of construction.

Sites to be used are the same as outlined above for water quality. With four transects each consisting of five sampling stations, 20 stations will be sampled on each survey.

Reporting of the fish stock surveys should include factual reports of:
a) All species caught (adult and juvenile) and estimated biomass of each species
b) Size-frequency and age frequency distributions for each species
c) Estimates of total fish yield in reaches upstream and downstream of the hydropower facility
d) Statistically significant changes in species composition throughout the year of monitoring

Fish catch surveys should be carried out at all major fish landing sites between Jinja as agreed between the parties.

Reports for this aspect of the study should include information on:
a) Numbers of boats operating at landing sites and estimates of full time jobs supported by fishery.
b) Records of all commercial and local food species being caught, and importance of each.
c) Estimates of total yield, including details of methodology for yield assessment.
d) Estimates of total commercial value of catch.
e) Details of non-commercial uses of fish (e.g. local consumption).
f) Estimates of value of any sport fishery.

Macrophytes surveys
a) Macrophyte surveys should be carried out at the same frequency as fishery and invertebrates surveys.
b) Surveys should be carried out on both sides of the river, and include all submerged or partially submerged plants and any plants growing on substrata which are likely to be submerged for a significant period of time.

c) Surveys should be carried out along a 1km length of each riverbank. Extending 500 m upstream of the centre of the transect used for water quality, fisheries and invertebrates surveys.

Macrophyte surveys should include recording of all species present, and an assessment of relative abundance against other species, using the DAFOR scale, as follows:

D = Dominant, A = Abundant, F = Frequent, O = Occasional, R = Rare.

This should include emergent species as well as submerged species, which may require collection with a grapnel hook or use of an underwater viewer.

Reporting should include:

- Lists (or completed checklists) of all species present
- Records of abundance using DAFOR scale.
- Maps of study reaches including locations of major macrophyte stands and estimates of percentage macrophyte cover.
- Identification of important habitats for fisheries, for example spawning areas
- Reporting of any natural seasonal variation in macrophyte species composition and cover.

				report compilation
Dr. J. S. Balirwa	BSc, MSc, PhD	Senior Research Officer	Aquatic ecologist	Assistant project manager, Fish biology and ecology studies and report compilation.
Dr. T. Twongo	BSc, MSc, PhD	Principal Research Officer	Aquatic biologist	Macrophytes and macro-invertebrates studies
Dr. L. Ndawula	BSc, MSc, PhD	Research Officer	Invertebrate ecologist	Micro-invertebrate studies
Mr. S.B Wandera	BSc, MSc	Research Officer	Fishery biologist and Taxonomist	Taxonomy, catch composition
Ms. G. Namulemo	BSc, MSc	Research Officer	Fishery biologist & ecologist	Taxonomy, relative abundance
Mr. D. Mbabazi	BSc. (Educ), MSc	Research Officer	Fishery biologist	Fish catch assessment and assists in report compilation
Mr. H. Oguttu	BSc	Research Assistant	Physico-chemical limnologist	Algal, primary production and physical-chemical studies.